History of Rocketry and Astronautics

Proceedings of the Seventh and Eighth History Symposia
of The International Academy of Astronautics

Baku, U.S.S.R., 1973

Amsterdam, The Netherlands, 1974

Kristan R. Lattu, Volume Editor

R. Cargill Hall, Series Editor

AAS History Series, Volume 8

A Supplement to Advances in the Astronautical Sciences

IAA History Symposia, Volume 3

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 0-87703-307-2 (Hard Cover)
ISBN 0-87703-308-0 (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 20

THE ROLE OF MIKHAIL K. TIKHONRAVOV IN THE DEVELOPMENT OF SOVIET ROCKET AND SPACE TECHNOLOGY*

Yu. V. Biryukov†

The life of the outstanding Soviet scientist and designer, Mikhail Klavdyevich Tikhonravov, is inseparably associated with the development of rocket and space technology, to which he gave more than half a century of continuous, creative service. His life embraced the development of practical cosmonautics from the simple designs of small liquid-propellant rockets that first took off into the air, to the most complex contemporary rocket and space systems that paved the way for man's mastery of space.

M. K. Tikhonravov was born to the family of a teacher on 29 July 1900, in a large provincial city of central Russia. In 1919 he volunteered and joined the ranks of the Red Army. As a young Red Army man, his devotion to the cause of the Revolution, his breadth of knowledge, and his great interest in aviation brought him to the attention of the command, and he was sent to a school organized in 1920, the Institute of Engineers of the Red Air Fleet, soon renamed the N. Ye. Zhukovsky Military Engineering Air Academy. At the academy, Tikhonravov obtained a thorough training in aeronautical theory and participated in the work of a small circle of glider enthusiasts. He and his comrades built a number of original gliders, and mastered the practical applications of their design, construction, and flight tests. Here, in 1920-1921, he was also introduced to the ideas of the founder of cosmonautics, K. E. Tsiolkovsky, first through his work and the lectures of Professor V. P. Vetchinkin, and, later, by listening to Tsiolkovsky himself when he appeared at the academy for conferences in 1923 and 1924.

The conferences on interplanetary flight, organized by a section of the military science society of the academy, also introduced Tikhonravov to the subject of rocket engineering, and impelled him to conduct calculations for a rocket airplane, but the results he obtained proved discomforting. Meanwhile, his work in aeronautics still satisfied the creative strivings of the young designer, and he did not immediately continue work in the field of reactive motion.

* Presented at the Eighth History of Astronautics Symposium of the International Academy of Astronautics, Amsterdam, 1974.

† Academy of Sciences, USSR.

On 25 April 1925, M. K. Tikhonravov numbered among the first graduates that finished the academy. He subsequently went to work in the department of land airplanes in Aircraft Plant No. 25, then headed by the outstanding aircraft designer, N. N. Polikarpov, where he was first involved in wing design and then with the engine-propeller group. Six years later, in 1931, Tikhonravov transferred to TsKB of the aircraft industry to head a group assigned to engine equipment. Tikhonravov's contributions to the history of aviation include participating in the creation of the gliders "Zmey Gorynych," "Firebirds," "Komsomol Truth," "Gamayun," and "Scyth" that established records in many glider competitions, and in the design of aircraft U-1, I-3, I-6, and R-5 that occupy a visible place in the history of Soviet aviation. From the very beginning of his work in the aircraft industry, the young engineer manifested a tendency toward the theoretical generalizations of practical design and teaching, which he undertook at the air force academy. Tikhonravov published his first book on *Aviation Fuel Tanks* in 1934, and another, *Power-Supply Systems and the Lubrication of Aircraft Engines*, in 1936.

Absorbed since childhood with the mechanism of the flight of insects and birds, in 1937, M. K. Tikhonravov published a monograph on the *Flight of Birds and Machines With Moving Wings*, (later reissued in 1949), that numbers among the most serious works on this problem in world literature. But from the end of the 1920s, as he immersed himself ever more deeply in the study of the theory and practice of flight techniques and became increasingly aware of the limitless prospects of reactive motion, the subject of rockets emerged to claim his attention. He focused on the design of rocket apparatus and equipment needed to supply propellants to the rocket engine.

In late 1931, Tikhonravov learned that F. A. Tsander, S. P. Korolev and other enthusiasts of rocket engineering had secured the aid of the voluntary defense society of Osoaviakhim to begin practical work on a rocket-propelled boost-glide vehicle. (This team was designated the Group for the Study of Jet Propulsion (GIRD) shortly thereafter in 1932.) Tikhonravov approached them with his ideas, projects, and calculations, and secured the support of S. P. Korolev. During April 1932, he joined in the formation of a second crew of GIRD, which planned to develop a pump fed oxygen-kerosene ZhRD [liquid-propellant rocket] designed 03, for use in the boost-glide vehicle RP-2. The crew also planned the development of rockets 05, using nitric acid and kerosene (designated ZhRD ORM-5)--designed by V. P. Glushko--and 07, another oxygen-kerosene ZhRD of their own design.

All of these projects were complex and difficult to achieve. They required the solution of a number of problems of liquid-propellant engine construction to create a flying rocket. The leadership of GIRD, consequently, decided to proceed on the basis of results obtained by the Baku GIRD, which featured the use of condensed gasoline as the simplest approach for realizing the design of a liquid-propellant rocket. This rocket became known as 09, or GIRD R-1, and was designed by M. K. Tikhonravov.

Using combustible condensed gasoline and liquid oxygen made it possible to inject the gasoline directly in the combustion chamber and, with the layer of fuel, shield the chamber walls from burn-through. One additional simplification consisted of supplying liquid oxygen, which served as the oxidizer, under the pressure of its inherent vapors. These daring engineering decisions of Tikhonravov predetermined developmental success. On the decision of the chief of GIRD, this work was declared primary and the engineers concentrated on it, while work on projects 05 and 07 was retarded. Design and construction of 09 accelerated and was completed in several months. In this case, the rocket was designated GIRD R-1, but in the historical literature it is usually named rocket 09, because the designation R-1 was also used for a number of other rockets.

In spite of its simplicity, 09 was not a project in the usual meaning of the word, but was rather a whole study program. The experimental development of this rocket began in March 1933. Many ideas remained unchecked; therefore, numerous assemblies and parts of the rocket were designed and manufactured concurrently in several versions. The superiority of one design over another, the suitability and advantages of the various versions of separate assemblies and parts of the rocket, frequently could be determined only experimentally. As a result, only the best of the designed versions were selected, and in a number of cases the designs underwent substantial changes. For project 09, as in all Soviet rocket projects at this early stage of contemporary rocket engineering, all of these changes occurred in the direction of simplifying the design.

The greatest difficulties appeared during early firing tests: fuel failed to ignite; during burning the spray of liquid oxygen eroded and burned the combustion chamber walls; condensed gasoline discharged from the chamber; the nozzle burned through; chamber blasts occurred during combustion. In all, 23 firing tests were conducted over two and one-half months. In this case, the engine tests of rocket 09 brought about changes in the material of the combustion chamber, the length of nozzle, and the area of its critical cross section, which altered combustion-chamber pressure. Other changes were made in the fuel injector plate, to prevent the condensed gasoline from overshooting the combustion chamber, and in the form and number of openings of the liquid-oxygen injector plate.

But in spite of all the difficulties, at the beginning of August 1933, bench tests demonstrated the successful operation of rocket engine 09. The rocket engine operated properly for 30 seconds at a full thrust of 53 kg, with a combustion-chamber pressure of 5-6 atm. It was then possible to install the engine in the rocket for flight tests, with definite confidence in its success. While the rocket engine was tested in the wind tunnel of the Moscow Aviation Institute, the missile body without the stabilizer, and with stabilizers of various shapes, also underwent wind-tunnel testing. These tests made it possible to specify the aerodynamic layout of the rocket.

Rocket R-1 (09) in its final form prepared for flight tests was a research craft consisting of an elongated cylindrical housing with an ogival head and a tapered, truncated tail section. Its overall length was 2285 mm, with a maximum diameter of 180 mm. The rocket consisted of four sections: parachute compartment, payload compartment, propellant tanks, and tail assembly.

The propellant compartment featured a long cylindrical oxygen tank. Above the tank there was a drain-reserve valve, and below, a tap and line that ensured the flow of oxygen into the engine. The mantle of this section was made from riveted aluminum alloy. The mantle of the payload was reinforced by stringers, and the mantle of the propellant compartment was reinforced by longitudinal corrugations. The rocket engine was installed within the tail section, which determined the diameter of the rocket, and the rocket had on the outside a four-finned aerodynamic stabilizer. The span of the horizontal stabilizer was 630 mm, and the area of each of the fins was 700 square centimeters.

The Rocket 09 had the following design characteristics:

- Launching weight -- 18.95 kg
- Payload -- 6.2 kg
- Reserve of fuel -- 7.82 kg
- Thrust -- 52.4 kg
- Specific thrust -- 164 kg s/kg
- Operating time of engine -- 15 sec
- Combustion chamber pressure -- 5 atm
- Initial thrust-weight ratio -- 0.36
- Maximum altitude of flight -- 5000 m
- Final speed -- 275 m/sec

Because of meticulous design, the rocket had a mass-ratio sufficiently good for that time: overall payload ratio consisted of 0.41, payload -- 0.33, and fuel -- 0.26.

In spite of the numerous firing tests and careful preparations for flight, two first attempts at launching did not succeed. Unforeseen trifles, a result of inexperience in launching liquid-propellant rockets, frustrated these attempts.

On 17 August 1933, a group of GIRD members headed by S. P. Korolev again brought the rocket to the training ground in the Nakhabino area of Moscow. The rocket was installed in the launcher with its guides made from metal tubes with a length of about 4 m, and was filled with gasoline and liquid oxygen. Preparations for the launching were carried out by a production team of GIRD, led by E. M. Matysik. N. I. Yefremov and Z. I. Kruglova were responsible for launch control from a nearby shelter. When the oxygen tank pressure reached 13.5 atmospheres, Korolev ignited the cord to the ejector of the parachute and departed from the launch pad. The launch control crew then applied current to the sparkplug; flame escaping from the nozzle marked ignition, and the rocket rose slowly from the launch tower. Sharply accelerating, it proceeded almost vertically. But suddenly, at an altitude of approximately 400 m, the rocket sharply changed direction and then, moving in a flat trajectory, flew into the forest.

The entire flight occupied 18 seconds. But these seconds completely justified the many months of the hard work of the GIRD members, demonstrating the ability of the GIRD team to solve the most complex problems that hinder development of new technology. The launching of this first Soviet liquid-propellant rocket testified to the strong efforts and organization of the GIRD members.

The rocket 09 achieved only ten percent of its rated altitude because a flange, which connected the combustion chamber at its bottom, had separated. Combustion gases flowed out at the rupture and created a lateral force, changing the rocket's direction of flight. This defect was easily remedied, and did not lessen in GIRD members' consciousness of a great technical victory. "The day of 17 August, when the first Soviet liquid-propellant rocket was launched, is undoubtedly a significant day in the life of GIRD and, from this time on, Soviet rockets must fly above the union of the republics," S. P. Korolev wrote in the wall-newspaper dedicated to the event.

The success of rocket 09 allowed S. P. Korolev, in his report to Osoaviakhim, to again raise the question about accelerating the creation of a formal jet propulsion institute, and he requested the allocation of 30,000 rubles for the construction of an experimental series of rockets. "It will be possible," wrote Korolev, "to make further improvements and obtain rockets of greater diameters, with flight speeds of up to 800-1000 m/s, capable of flying at ranges of several hundreds and thousands of kilometers." Today, our rockets attain speeds of 8-10 km/s and possess ranges of many thousands of kilometers, but the Soviet people will never forget that this path into space began on 17 August 1933.

Indeed, the Jet Propulsion Research Institute (RNII) was formed at the end of 1933, composed of the cadres from GIRD and the Gas Dynamics Laboratory (GDL). M. K. Tikhonravov was named the first head of the department that developed ZhRD liquid-propellant rockets, which continued the work of the first and second crews of GIRD. The efforts of this department led in particular to the successful flight tests of the Tikhonravov-designed rockets 07 and 05, and a new oxygen-alcohol ZhRD 12, named for the "All-Union Aviation Scientific, Engineering, and Technical Society (1932-1941)." This latter rocket had a launching weight of 97 kg and, in a flight on 13 August 1937, reached an altitude of approximately 3000 m.

The bright achievement of the first years of work on these rockets, when each rocket flight was considered a great accomplishment at RNII, soon changed into persistent, tedious efforts directed toward perfecting reliable designs that solved not only experimental, but also practical problems. This work required thorough scientific research, and Tikhonravov gradually concentrated his primary attention on this aspect of rocket engineering, one that combined serious theoretical studies with sound experimental programs. In essence, the work concentrated around three problems that were central to rocket engineering during the middle 1930s: the problem of the combustion process in ZhRD, the problem of stability of the rocket in flight, and the problem of supplying propellants into the combustion chamber of ZhRDs. One after another, Tikhonravov published his findings in scientific works, each of which found immediate application in the practical activity of designers. Chief among these works were two articles on "The Stability of Vertical Rocket Flight" (1935) and (1933), an article, "Experimental Rocket-motor Characteristics"

(1938), and two more on the "Investigation of the Factors that Affect the Closely Grouped Fire of Rocket Projectiles" (1938) and (1939). The latter articles played a significant role in the selection of the final launching configuration of the "Katyusha Rocket Launcher."

Although focused on specific scientific problems of rocket engineering, Tikhonravov at the same time never separated himself from the general problems of engineering development, and the contemporary and future prospects for the application of rockets. On one hand, he investigated the prospects for creating rockets for upper atmospheric research, and reported these results at the All-Union Conference on the Study of the Stratosphere, called by the USSR Academy of Sciences in the spring of 1934, and again at the All-Union Conference on the Application of Rockets to the Mastery of the Stratosphere, hosted by the All-Union Aviation Scientific, Engineering, and Technical Society (1932-1941) and RNII in the spring of 1935. In these reports, he showed that rocket engineering had reached a level that would permit building stratospheric rockets that could carry instruments to an altitude of 50 km, and outlined ways of creating other high-altitude rockets. On the other hand, Tikhonravov searched for ways to achieve space flight. Among the most interesting and creative was his article "Ways of Using Radiant Energy for Space Flight" published in 1936, in which he described an original project for realizing a lunar expedition. Assuming the use of solar energy as the basis of the spacecraft design, Tikhonravov demonstrated well his knowledge of the ideas of K. E. Tsiolkovsky. In fact, he visited Kaluga [Tsiolkovsky's home] during February 1934, which prompted him to pay increasing attention to cosmonautics. In a press article in 1935 he emphasized the need for human settlement in outer space, as one aspect of the teaching of K. E. Tsiolkovsky's concepts.

It was characteristic of Tikhonravov to address polemical scientific issues. As an example, he disproved the opinions of those who resisted the development of rocket engineering in his articles, "About the Effect of Inert Impurities in Solid Propellant on the Thrust Level of Rockets" (1937), and the "Value of Specific Gravity in the Selection of Propellants for Rockets" (1938). Moreover, in both these articles he demonstrated that Tsiolkovsky was correct, and not those who attempted to reexamine his criteria of the effectiveness of rocket propellants. In 1939 Tikhonravov published the article, "The Work of Tsiolkovsky and Contemporary Missile Construction." From this time forward he committed himself to rocket techniques in space, edited the first postwar republications of the fundamental works of Tsiolkovsky and Tsander, and published a whole series of interesting articles.

In 1944 Tikhonravov directed the design and construction of a four-stage rocket for cosmic-ray research, which was successfully tested. An enthusiast of space technology in the early 1950s, he developed theoretical calculations for artificial Earth satellites, and, under Sergey Pavlovich Korolev's leadership, took a most active and direct part in the practical implementation of the Soviet space program that resulted in the launching of the first artificial Earth satellites, lunar and automatic interplanetary stations, and the first flights of man into space.

During all these years of intense labor on the leading edge of science and technology, Mikhail Klavdyevich still found time to participate in the large-scale training of personnel and in propagating the ideas of cosmonautics. For many years he served as a professor at the Moscow Aviation Institute, and tens of his pupils number today among the leading specialists of space technology. Mikhail Klavdyevich devoted great attention to training scientific cadres, counseling graduate students, working in a number of academic councils and on the editorial boards of scientific publications, and to publishing the works of Tsiolkovsky and other pioneers of cosmonautics.

For his great services to the Soviet people and personal contributions to resolving numerous crucial problems of space science and technology, Mikhail Klavdyevich Tikhonravov was awarded the high title of Lenin Prize Winner, Hero of Socialist Labor, Honored Scientist and Technologist of the RSFSR, among many other orders and medals of the Soviet Union. His work became widely known, not only in our country, but also throughout the entire world. Recently, he was elected a corresponding member of the International Academy of Astronautics. The name of M. K. Tikhonravov, one of the nearest companions-in-arms of S. P. Korolev, who made great scientific contributions to the theory and practice of rocket engineering and cosmonautics, will be enshrined forever in the history of man's mastery of outer space.