# History of Rocketry and Astronautics

**Proceedings of the Twenty-Second and Twenty-Third History Symposia of the International Academy of Astronautics**

**Bangalore, India, 1988**
**Málaga, Spain, 1989**

**John Becklake, Volume Editor**

**R. Cargill Hall, Series Editor**

## AAS History Series, Volume 17

**A Supplement to Advances in the Astronautical Sciences**

**IAA History Symposia, Volume 10**

AAS Publications Office
P.O. Box 28130
San Diego, California 92198

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

*First Printing 1995*

ISSN 0730-3564

ISBN 0-87703-395-1 (Hard Cover)
ISBN 0-87703-396-X (Soft Cover)

Published for the American Astronautical Society
by Univelt, Incorporated, P.O. Box 28130, San Diego, California 92198

Printed and Bound in the U.S.A.

## Chapter 24

# The Role of Mikhail Klavdiyevich Tikhonravov in Creating Stage Rockets, 1947-1953[1]

I. M. Yatsunsky[2]

In the life and activities of Mikhail Klavdiyevich Tikhonravov, the period of 1947 to 1953 (inclusive) was a determining and crucial one. It was during that time that he took the first steps to help translate into reality the dream of K. E. Tsiolkovsky about space flight within the coming few years.

The situation at the research institute where Academician Tikhonravov worked developed as follows. The VR-190 project was, in 1947, handed over to a special subdivision, where it was given a somewhat different tenor and designated a "probe rocket." Some time later M. K. Tikhonravov withdrew from that work and, holding then the office of Deputy Head of the Institute for one of its specialities, he established a new department under P. I. Ivanov. According to Academician Tikhonravov's idea, this department was to work out, among other things, the theory of multistage rockets, including lateral-staging ones. And at that juncture, Mikhail Tikhonravov, heeding the lessons of the vertical-ascent rocket project, succeeded in producing a technological solution resulting in a feasible design for the engineering development level of that time. Two main separation arrangements for multistage rockets: tandem and clustered ones were known. The tandem arrangement of rocket stages, in spite of the seeming simplicity of the configuration, entailed an unsolved problem—that of starting an engine in a vacuum, on a trajectory. As an engineer, Academician Tikhonravov could see another major drawback of the tandem arrangement when used in a space rocket; this is its great length. He realized the fundamental difference between the construction of a multistory

[1] Presented at the Twenty-Second History Symposium of the International Academy of Astronautics, Bangalore, India, 1988.

[2] Intercosmos Council, U.S.S.R. Academy of Sciences, Moscow, U.S.S.R.

building, or a tower fixed to the Earth, and a big rocket meant to fly into space, to put a sputnik into orbit and attain cosmic speeds.

Academician Tikhonravov considered it an extremely complicated affair to create such a rocket at that time. So he addressed himself to the clustered configuration of stage rockets: all the engines are fired on the Earth. The length of a rocket is much less than that of a tandem version and is equal to the length of the largest rocket forming the cluster (or "pack"). He attached special importance to clusters made of different rockets, among which there might be rockets fired on a trajectory, and he referred to such rocket packs as "complexes." Mikhail Tikhonravov held that the problem of igniting an engine in a vacuum would be solved sooner than that of creating a very big rocket with a high ratio of total length to maximum transverse dimension.

Compared to K. E. Tsiolkovsky's rocket trains, clusters were more constructive. They took into account the technological opportunities of rocket production in post-war times. They can be assembled in a rigid way, which rules out the need for reciprocally controlling the flight (as in Tsiolkovsky's case), and they retain the possibility, at least in principle, of using their component parts separately.

In the initial phase of work, when the significance of using rockets forming a cluster might not be preserved, this design proved most acceptable for that time. The theory belongs to our compatriot, Yu. V. Kondratyuk, another pioneer of rocket-and-space technology.

The assignments given by M. K. Tikhonravov to Ivanov's department of stage rockets, consisted of refining the theory of the optimum selection of major design-and-ballistic parameters of such rockets (clusters in particular) and of producing methods of calculating the trajectory. At that time (1947-1948), no electronic computers were available, so all the calculations required had to be performed "manually," i.e. on simple calculating machines. Nevertheless, despite the very slow speed of computation by that method, a preliminary report was issued in late 1947, dealing with the theory of (multi-) stage rockets, wherein lateral-staging rockets were also covered to a first approximation.

In 1948, the work was continued. At that time individual articles on the theory of multi-stage rockets began to appear in the U.S. press. Naturally, they could not take into account the peculiarities of Soviet rocket production experience, which influenced the design-and-ballistic parameters of stage rockets created in this country. Neither were the peculiarities of their trajectories taken into consideration.

Academician Tikhonravov closely followed the work on staged rockets and guided it in the right direction. Much time had to be spent on fitting clusters made up of identical rockets within the general theory of stage rockets being put forth, where the number and magnitude of jettisonable masses obey the laws of mathematical optimization only. But here we had to allow for the fact that the ejection of masses could only occur as whole single rockets or groups of rockets. Certain factors emerged which Academician Tikhonravov liked, so he decided to make a report at a meeting of the Academic Council of the Institute. It was the summer of 1948. In the conference hall of the Institute, where the meeting was held, many invited persons, and those simply interested in the problems, were sitting next to council members. The audience was divided over Tikhonravov's report. Many people wanted to speak, mounted the rostrum, drew a rocket pack with chalk and said it would not fly, owing to its poor aerodynamics. Others pointed to

the unreliability of the connections of the cluster. The few supporters among the speakers said that, as calculations had shown, aerodynamics did not matter much for ballistic rockets, particularly for stage rockets with mass jettisoning, that the connection of rockets was a simple design job, and so on.

That report of M. K. Tikhonravov was of great interest due to the novelty of the problem raised, namely, the description of a rocket flying into the upper layers of the atmosphere with a speed over four times more than that of contemporary rockets. On 14 July 1948 Academician Tikhonravov repeated his report to a larger audience. As with the first presentation, this was heard with tremendous attention and in absolute silence. In that nearly solemn quiet, Mikhail Tikhonravov's voice sounded somehow especially calm. He seemed to be speaking the way he always did when explaining something: without superfluous affectation, simply, using no complicated expressions.

At the same time, one could feel an enormous inner concentration on the report theme, a desire to speak in such a way that listeners might, as it were, imbibe each word and comprehend its meaning. All that came most naturally to Mikhail Tikhonravov, his ability to bring his thoughts home to listeners was always striking.

Immediately following the report, work started in our department of the Institute on issuing a new report dealing with the theory of stage rockets, including the clustered type. That took a lot of time and, understanding it, Academician Tikhonravov tried to give us no additional assignments. However, he suggested that, parallel to the report, I should write an article on the same subject and publish it in one of the scientific journals. I wrote such an article, but as a result of a delay in publishing, it did not appear until 1950. It is characteristic that in his report issued in 1948, Academician Tikhonravov included a reference to the article in question, but, as it had not been printed yet, he put dots in place of the journal number.

The beginning of 1949 was especially unfortunate for further progress of the work on staged rockets. The relevant department of the Institute was abolished. With great difficulty Academician Tikhonravov managed to preserve only one person (myself) for his work.

Fulfilling a personal assignment for M. K. Tikhonravov, and being a staff member of a department having little in common, I seldom contacted him. During our meetings we mainly dealt with the issue of setting up a future group, that might continue the work on stage rockets directly under the guidance of Academician Tikhonravov. His hope was that, in the end, he would be allowed to form such a group. And soon he achieved his objective.

In late 1949, M. K. Tikhonravov's group included young engineers G. Yu. Maximov, L. N. Soldatova, A. V. Brykov and Ya. I. Koltunov. The first three worked in the group until the end of its existence (1956), and Ya. I. Koltunov transferred in 1951 to another subdivision of our Institute. In spite of that, he maintained his relations with the group for a long time. In 1950, the group on stage rockets enlisted the services of G. M. Moskalenko, who had previously worked on the "probe rocket" in another subdivision. Also in 1950, the group was joined by B. S. Razumikhin, who remained its staff member until 1952. G. M. Moskalenko participated in the design activities of the group until 1953. From 1953 to 1956, design jobs in the group were performed by V. N. Galkovsky.

Back in the late 1940s, M. K. Tikhonravov supervised the work of a small circle of students, who enthusiastically studied the books by K. E. Tsiolkovsky and other classics of cosmonautics. In 1951, two members of that circle, I. K. Bazhinov and O. V. Gurko, joined M. K. Tikhonravov's group after graduation and remained with it until it ceased existing.

In mid-1949, Academician Tikhonravov paid special attention to a graph prepared by me on the basis of calculations made shortly before that. In the graph, I plotted a curve showing what the relative weight of the rocket might be for the stage number of n = 3, with an approximately optimal sign efficiency coefficient and of specific thrust. (The calculations had been made with due regard for a rational path of orbit injection).

Academician Tikhonravov requested that those calculations should be applied to clusters made of rockets being developed at that time in the Experimental Design Bureau (OKB) under Academician S. P. Korolyov. This was done immediately.

Apparently the results were quite new, for Academician Tikhonravov said he would invite Sergei Pavlovich Korolyov, so that he could familiarize himself with them. S. P. Korolyov came sometime in July or August of 1949. Having seen the graphs, he at once grasped the high significance of the results obtained. "You are capital engineers," he said. Probably it was after that visit that a decision was taken to hear M. K. Tikhonravov's report, entitled "Rocket packs and their development prospects," at the scheduled scientific-technological conference of the Institute.

The conference took place in March, 1950. Academician Tikhonravov delivered his second public report, in which, for the first time, he spoke directly of the immediate outlook for landing an artificial Earth satellite, including man's mission in it. M. K. Tikhonravov's report was listened to attentively, but the response of those present was varied. Some spoke ironically of what they had heard, others were incredulously silent, and only a few of the rocket engineering specialists understood that they had been offered a presentation of the initial findings of a promising scientific-technological trend. The conference was attended by Academician S. P. Korolyov and one of his deputies.

1950 was a year of strenuous work for M. K. Tikhonravov's group, when the academician's special style in research work manifested itself fully. The idea was that each participant received, as far as possible, a separate assignment in which he was interested. He proceeded with this assignment independently, turning, in case of need, to the leader or some of his colleagues for advice. In the group there reigned a truly creative atmosphere of respect and goodwill towards each other. Everyone appreciated that his work was dedicated to a single great goal and performed it with the utmost conscientiousness. Within a comparatively short time we had worked out (at a sketch level) various configurations of clustered and tandem stage rockets and devised a mathematical method of weight analysis on the basis of statistics made available by the Korolyov OKB (the method subsequently formed part of G. M. Moskalenko's book "Engineering Methods of Designing in Rocket Dynamics"). We had conducted ballistic investigations of powered portions of trajectories, specified the method of selecting the design-and-ballistic parameters of stage rockets and packs, and solved problems of structural links of individual rockets in a pack, problems of starting, etc. The most promising area of research was the one elaborated by G. Yu. Maximov, jointly with M. K. Tikhonravov, devoted to the cosmic ballistics of artificial Earth satellites. A number of problems were solved for

optimizing inter-orbital transfers and de-orbiting. The power requirement for these maneuvers were estimated. The first investigations of the flight stability of a rocket pack were also made, and encouraging results were obtained. All that voluminous material was included in a report consisting of three books and issued in late 1950. A close relationship was established in 1950 with the Korolyov OKB, where various rocket designs were being developed.

In 1950, a two-stage pack of three powerful rockets was studied, which were the latest to have been developed by the Korolyov OKB. An analysis of the motion of such a cluster showed that it was capable of putting into orbit a fairly heavy artificial Earth satellite. It was perhaps the first study of the problem of launching a Sputnik in the U.S.S.R., based on concrete designs of single-stage rockets, so the results were practicable.

The assistance provided to M. K. Tikhonravov's group by the Korolyov OKB, in terms of substantiating the dependences of the weight characteristics of rockets, were extremely useful for elaborating the theory of lateral-staging rockets. One of these, the simplest pack configuration, was especially liked by Academician S. P. Korolyov. However, for all its simplicity, the rocket turned out to be much heavier than other, more sophisticated arrangements. It was necessary to optimize the simplest cluster. In 1951, the general mathematical relations required for that and other solutions were obtained by the group and expounded in two reports, but the optimization itself was not carried out.

This was not because of the complexity of the problem, for it was clear already that the rocket was to be a two-stage one, and the optimization could be performed by a mere enumeration of the major parameters, but it was because of the absence of a clear-cut need for making that optimization. It was at variance with Academician Tikhonravov's idea of preserving individual independent rockets in a pack—an exceedingly fruitful idea, but somewhat too complicated to be realized in the first phase.

Evidently, Academician S. P. Korolyov realized the prevailing situation very well, and he asked Academician M. V. Keldysh to continue research for solving that particular problem in the Department of Applied Mathematics (the Institute of Mathematics named after V. A. Steklov, the U.S.S.R. Academy of Sciences), since important relevant results have already been obtained there. The problem was solved by D. Ye. Okhotsimsky, a worker of the said department, under the supervision of M. V. Keldysh. The former described the general methods of optimization and obtained the optimum parameter values for a two-stage rocket of the simplest pack configuration. Following that optimization, the launch weight happened to be practically identical to that of other, more sophisticated clusters. The work enabled S. P. Korolyov to make a decision concerning the development of an optimally configured two-stage simplest cluster.

In the course of the next two years (1952-1953), we solved specific, but very important problems related to the design of a two-stage rocket. These included such problems as trajectory measurement, motion control and test site selection.

The contribution of Tikhonravov's group to that common cause, appreciable though it was, could not compare to its significance in the previous years. In 1952-1953 and early 1954, M. K. Tikhonravov and his group prepared three memoranda. These reflected the results of unofficial research on artificial Earth satellites carried on by the group. It demonstrated what kind of Sputniks could be launched by the two-stage rocket

developed by Korolyov, what equipment could be placed in them, how they were to be controlled what had to be available there for the purpose (orientation system, thermal protection, etc.), and, in conclusion, which problems, in the interest of science and mankind, they were in a position to solve. In essence, those were brief scientific-technological reports on the research undertaken.

As proved later, the memoranda in question were destined to play a major part in orientating the Korolyov OKB towards creating artificial Earth satellites and to cosmic subjects on the whole. 1953 terminated in a highly important event: the Institute started a two year research program, dealing with problems of creating artificial Earth satellites, and which was conducted by the group under M. K. Tikhonravov.

The analysis of that research, as well as of a number of events which occurred at that time which influenced the formation of space science and technology, exceeds the limits of the period under review (1947 through 1953), and must be set forth separately.