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 6

ORGANIZATION AND RESULTS OF THE WORK OF THE FIRST SCIENTIFIC CENTERS FOR ROCKET TECHNOLOGY IN THE USSR*

I. A. Merkulov†

Rocket technology is the technical base for contemporary achievements of cosmonautics. The USSR's successes in launching the first artificial Earth satellites and the first automatic interplanetary stations to the Moon, Venus and Mars, in accomplishing the first orbital manned flight and other outstanding accomplishments in the area of the study and exploration of space, were due to a significant degree to the early start of work on rocket technology.

At the IAF [International Astronautical Federation] congresses, beginning with the 18th Congress, which took place in Belgrade in 1967, in a number of reports, many questions on the history of Soviet space rocket technology have already been dealt with. In the present report, an attempt is made to tell about all the largest organizations that were working in the USSR in the 1920's and 1930's in the field of rocket technology. At the same time, it was kept in mind that in those years all the various work on the development of scientific rockets, combat rockets and jet engine planes was considered as one scientific problem. This problem was frequently designated by the term "the problem of jet propulsion." The theoretical bases for all these highly diverse branches of technology were included in a concept -- the theory of jet propulsion. Therefore, in dealing with the results of the activities of the first scientific centers, which worked in the field of jet propulsion, it has been recognized as expedient to note all the variety of their achievements in the field of the problem of jet propulsion.

N. I. TIKHOMIROV'S JET PROPULSION LABORATORY

The first Soviet scientific research and experimental design organization for the development of jet engines and rockets was established in Moscow in March 1921 on the initiative of the engineer-chemist, N.I. Tikhomirov, and at first was

---

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

† Committee of the Soviet National Association of Natural Science and Technology Historians, USSR Academy of Sciences, Moscow, USSR.

called the "Laboratory for the Development of the Inventions of .I. Tikhomirov." It was located on Tikhvinskaya Street in the two-story building No. 3, where a pyrotechnical and chemical laboratory and a machine shop were set up [1, p. 101]. Its task was the development of rockets that operated on smokeless powder.

N.I. Tikhomirov and his talented assistant, V.A. Artemyev, who had begun working on the improvement of powder rockets even before the First World War, performed a large amount of work on the selection of the composition of smokeless powder, on working out the technology for the production of powder charges and on the study of the process of their combustion in jet engine chambers. They involved in this work a number of scientific institutes, mainly in Leningrad. And at the beginning of 1924, the first models of charges with nitrocellulose-trinitrotoluene (TNT) powder were produced. The biggest contribution to the development of the methods for obtaining such powder was made by O.G. Filippov and S.A. Serikov.

In March and April 1924, V.A. Artemyev conducted tests at the main artillery firing range in Leningrad of projectiles with rocket engines installed on them, which worked on smokeless powder. During the tests, 21 projectiles were launched and a ten-fold increase in distance was obtained in comparison to the initial projectiles without rocket engines [1, p 102].

Inasmuch as the basic work on rocket engines using smokeless powder was conducted in Leningrad in 1927, the laboratory was transferred completely to this city. In the documents of that time, it was frequently called N.I. Tikhomirov's Jet Propulsion Laboratory. Through the efforts of its staff in 1928, the first Soviet rockets using smokeless powder were developed. On 3 March 1928, successful launches took place at the Scientific Testing Artillery Firing Range (STAFR). As a result of the immense achievements in the development of rockets with solid-propellant engines (SPRE), N.I. Tikhomirov's Jet Propulsion Laboratory was expanded in June 1928, when it received the name the Gas Dynamics Laboratory (GDL).

THE GAS DYNAMICS LABORATORY

In 1928, the GDL was located on the STAFR and made widespread use of its laboratories and shops. In 1932, it obtained 12 rooms in the central section of the Main Admiralty and the Ioanovskiy Ravelin building in the Petropavlovsk Fortress. With each passing year, the number of GDL associates increased. In September of 1930, there were 23 people working there, at the end of 1931 -- 77, in December of 1932 -- 120 and at the beginning of 1933, the number of associates grew to nearly 200 people [1, pp 103-105]. In April of 1930, the permanent leader of the laboratory, N.I. Tikhomirov, died and B.S. Petropavlovskiy became chief.

An important event in the development of Soviet rocket technology was the organization, on 15 May 1929, within the make-up of the GDL upon the initiative of V.P. Glushko, of a subunit on electrical and liquid-propellant rocket engines [LPRE] and rockets. This subunit, which soon grew into a large branch, was the first state scientific organization for space-oriented rocket technology.

In 1931, in the make-up of the GDL, there were seven sectors operating: G.E. Langemak headed the sector on powder rockets, V.P. Glushko -- the sector on solid-propellant rockets [SPR], V.I. Dudakov -- the sector on aviation use of powder rockets, N.A. Dorovlev -- the mortar sector, I.I. Kulagin -- the sector on powder production, Ye. S. Petrov -- the production sector, and V.A. Krasovskiy -- the administrative management sector [1, p 105].

The GDL successfully continued the work begun by N.I. Tikhomirov on the development of rockets using smokeless powder. Under the supervision of B.S. Petropavlovskiy, a study was conducted on the laws of combustion of powder charges in rocket chambers, and the design elements of the rocket engines, the rockets and the launching devices, were worked out. In 1930-1931, in the GDL, 82mm and 132mm caliber powder rockets were developed that were intended to be used as jet propulsion rockets. And in the summer of 1932, the first official firings in the air of the RS-82 rockets from the I-4 aircraft were conducted. In that same year, tests were begun on arming the R-5 aircraft with the RS-82 and RS-132 rockets and the TB-1 aircraft with the 132 and 245mm caliber jet propulsion rockets [1, p 104].

Under V.A. Artemyev's supervision, in the GDL, flares, signal flares and propaganda rockets using smokeless powder engines were demonstrated.

In evaluating the results of the GDL's work in the field of powder rockets, Academician V.P. Glushko wrote: "By the end of 1933, the GDL had had large-scale achievements in the development of rockets using smokeless powder. In all, in the GDL by the end of 1933, nine types of various caliber and purpose rockets had been developed and adopted.

B.S. Petropavlovskiy, G.E. Langemak and V.A. Artemyev are the main authors of these developments begun earlier by N.I. Tikhomirov" [1, p 107].

In the GDL, work on rocket launching of the U-1, TB-1 and TB-3 aircraft was carried out successfully under the supervision of V.I. Dudakov. On 14 October 1933, state tests were conducted on the TB-1 aircraft equipped with smokeless rocket engines. Thanks to the action of the SPRE, the length of an aircraft's take-off run was reduced by 77 percent. work was also carried out on rocket catapulting and deceleration of aircraft [1, pp 104-105].

Highly successful was the GDL's work on electric rocket engines (ERE) and LPREs. In 1929-1931, V.P. Glushko designed the world's first electrothermal rocket engine and LPRE: the ORM, ORM-1 and ORM-2, which were developed and tested in those same years. In 1932, the ORM series of LPRE's from ORM-4 to ORM-22 were constructed.

In 1932, one of the leading scientists from TsaAGI [The Central Aerohydrodynamics Institute -- CAHI], Professor V.P. Vetchinkin, attended the ORM-9 engine tests in the GDL. In his own review, he wrote: "In the GDL, the main part of the work for the realization of the rocket -- the solid propellant jet propulsion engine -- was performed ... From this point of view, the GDL's achievements (mainly those of Engineer Glushko) must be recognized as brilliant" [5, p 13].

Simultaneous with the development of the LPRE in the GDL, work was carried out on the development of rockets. In 1932, a plan for a rocket based on the design of Glushko, the RLA-100 with a lift altitude of 100 km, was developed there. Its launch weight amounted to 400 kg. The nitric acid LPRE with a reinforced universal joint should have developed a thrust of 3,000 k during an operating period of 20 sec. The production of three sets of the RLA-100 rockets was started at the Machine Building Plant in the city of Perm, but was never completed [17, p 712].

In order to speed up the flight tests of the engines with thrusts up to 300 kg, checks of the rocket launch and control methods were developed in the GDL in 1933, and stand test firings of the RLA-1 and RLA-2 rockets for vertical flight to an altitude of 2-4 km from the launch table without a guidance device were prepared and conducted. Plans were made and work begun on the RLA-3 guided rocket. Within its body there was an instrument compartment with two gyroscopic devices, which guided it using pneumatic servo devices and the mechanical drafts of two pairs of air vanes located in the tail unit.

In 1933, there were test stand firings of the ORM-23 through ORM-52 engines in the GDL. The results of the GDL's work on the development of LPRE's were expressed in the following manner by Academician V.P. Glushko:

> "By the end of 1933, in the GDL, they overcame the basic difficulties associated with ensuring the reliable operation of LPRE's. Hypergolic and pyrotechnical ignition, centrifugal burners, a spirally finned nozzle dynamically cooled by the fuel component, the internal cooling of the walls of the combustion chamber by the fuel screen, the successfully selected construction materials made it possible to achieve the repeated operation of engines at a pressure in the chamber of 20-25 ATA and a specific impulse of 200-210 sec using a nitric acid-kerosene fuel. This was supported by the official tests conducted in 1933 on the ORM-50 engine with a thrust of 150 kg and the ORM-52 with a thrust of 300 kg, which were intended for rockets, hydroplane torpedoes and aircraft. Over the course of 10 launches, the ORM-50 model worked 314 sec and remained whole. The ORM-52 model worked 533 sec. during 29 launches and maintained its operations capacity [3, pp 112-113]".

As a result of the work of the GDL staff, the foundations for subsequent Soviet rocket engine construction were laid. From inside the GDL walls came the basic staffs that formed the creative collective of the Experimental Design Bureau, the GDL-EDB, which developed the powerful LPRE's for all Soviet launch vehicles that have flown into space.

JET PROPULSION STUDY GROUP

In September 1931, at the Central Council of the USSR Osoaviakhim [Society for Promoting Defense and Aviation and Chemical Construction], within the make-up of the Air Technology Bureau, the Jet Propulsion Study Group [GIRD -- JPSG] was organized. Its first chairman was F.A. Tsander. The group promoted scientific propaganda on the problems of rocket technology and paid a lot of attention to the training of rocket construction personnel. In the spring of 1932, in the JPSG engineering and design courses on rocket technology were organized -- a type of short-term institute.

In April of 1932, the JPSG obtained space in the basement of building No. 19 on Sadovo-Spasskaya Street in Moscow, which became the birthplace of the first Soviet liquid propellant rockets [LPR]. There the necessary experimental and testing and production base was established and the basic work was conducted. The successful activities of the JPSG led to the fact that in 1932 the group was transformed from a social organization into a state scientific research organization, which was headed up by S.P. Korolev since 1 May 1932 [25].

Within the JPSG, four design units were organized. The first developed the LPRE's, and in particular, the ORM-2 oxygen alcohol aviation LPRE, and designed the GIRD-10 LPR. This unit was headed up by Tsander. The second JPSG unit, led by the experienced aviation designer, M.K. Tikhonravov, designed LPR's and LPRE's and developed the pumping unit for feeding fuel into the LPRE chamber.

The third unit, headed up by Yu. A. Pobedonostsev, developed and tested on the stand and in flight the world's first ramjet engines -- the GIRD-08. The JPSG's fourth group, headed by S.P. Korolev and Ye. S. Shchetinkov, designed the world's first winged LPR, the GIRD-06, and began conducting flights tests on the BICh-11 airframe designed by B.I. Cheranovskiy, for which Tsander's unit developed LPRE's [7-13].

All four units were part of the JPSG's first department, which was entrusted with the scientific research and testing and experimentation work. The Second Department took care of the administrative and managerial work. The third department was the mass organization department and conducted scientific and technical propaganda on rocket technology. The fourth department was called the JPSG's pilot production department [11, 12].

The USSR's first rocket range for test flights of rockets was established in the forest in the vicinity of Nakhabino Station outside Moscow.

The first Soviet LPR was the "09" rocket designed by M.K. Tikhonravov. Its flight on 17 August 1933, represented an important step in the formation of Soviet rocket production. On 6 November, the second flight of the updated model of the rocket, designated "13," took place. And on 25 November they launched in Nakhabino the second JPSG rocket, the design of which was started under the supervision of Tsander, the GIRD-10. During 1933, the JPSG staff designed and built two more LPR's, the "07" and the "05," which subsequently made several flights. The latter, which had completed flights using the 12k oxygen-alcohol LPRE, is well-known under the name "Aviavnito" [The All-Union Scientific and Engineering Technology Society of the Aviation Industry].

The example of the tests on the first LPR, the GIRD-09 in 1933, tells convincingly of the care exercised during the testing of the rockets. In the archives, 17 documents on the testing of the rocket units, 3 on the testing of the engines, 25 on the rocket combustion tests and 7 on rocket launches have been preserved [17]. In the following year, tests were continued and a number of ground tests were conducted, as well as three rocket launches into the air [18]. In those cases the rockets ascended to an altitude of 1,500 m.

The solution by the JPSG staff of the problem of developing an LPR exerted a great deal of influence on the further development of rocket technology in the Soviet Union.

JET PROPULSION SCIENTIFIC RESEARCH INSTITUTE

The JPSG's successful work on LPR's and the GDL's work on the development of LPRE's and SPR's were the basis for the organization within the Soviet Union of the world's first Jet Propulsion Scientific Research Institute (JPSRI). It was established by a resolution of the USSR Council of Labor and Defense in October 1933, based on the GDL and the JPSG, and joined the system of the People's Commissariat for Heavy Industry. In the JPSRI, they developed a broad front of complex scientific research and planning and design work on all the basic directions of rocket technology.

In the JPSRI, they continued the work begun in the JPSG on LPR's. Flight tests were conducted on the "13" rocket, during which it reached an altitude of 1,500 m, and there were launches of the "07" and "Aviavnito" rockets. Four more LPR's were designed in 1936-1937, with various LPRE's, based on the "09" rocket designed by M.K. Tikhonravov.

The JPSRI staff continued the GDL's work on smokeless powder rocket engines. Here, they completed the development of the RS-82 and RS-132 powder rockets, which were intended to be installed on aircraft. They were installed on the IL-2 [Ilyushin], Yak [Yakovlev] and La [Lavochkin] aircraft.

In the JPSRI, they also developed the BM-13-16 mobile rocket launches, the so-called guardian mortars that played an exceptionally large role during the years of the Second World War.

A large achievement of the JPSRI staff was the development of the nitric acid-kerosene and oxygen-alcohol LPRE's. The staff of LPRE specialists, trained in the GDL, continued on the JPSRI under the supervision of Glushko to develop the family of ORM engines.

Over the years 1934-1938, single-chamber and twin-chamber designs with thrusts of up to 600 kg were developed. The ORM-53 through -70 engines operated on nitric acid, while the ORM-101 and -102 used tetranitromethane as the oxidizer. Of particularly great importance was, at that time, the development of the ORM-65 engine, which was officially tested in 1936. It operated on nitric acid and kerosene. The amount of its thrust was controlled during the flight from 50 to 175 kg. It was intended for the RP-318-1 rocket plane and the 212 winged rocket, both designed by Korolev. The ORM-65 engine was the homeland's best LPRE of the time.

In the JPSIR, in 1937, they developed the first GG-1 gas generator. It produced 40-70 hp from gas with a pressure of 20-25 ATA and a temperature of 450-580 degrees C for supplying power to a turbine or a piston engine, which start the fuel pumps going.

In the JPSRI, they completed the construction of the world's first winged LPR, the "06," designed by Korolev. And on 23 May 1934, it completed its first test flight. The institute's staff designed and built three more types of winged rockets with LPRE's: the 216, the 212 and the 301 and one winged rocket with an SPRE [15].

The most interesting rocket was the 212 model designed by Korolev. It had automatic launching, stabilization and guidance systems. The wing span amounted to 8.06 meters and the area to 4.7 m^2. The payload size was 30 kg. The estimated flying range was 50 km [15].

In the JPSRI, under the supervision of Yu. A. Pobedonostsev and M.S. Kisenko, three series of flight tests of the "08" ramjet engine, placed in the body of an artillery shell, were conducted in the years 1934-1936 [26].

In the JPSRI, under the supervision of Pobedonostsev, they developed and operated successfully the USSR's first supersonic wind tunnel with a (Töpler) unit, which made it possible to visualize the gas flow.

Extremely interesting was the work on the development of and the flight tests for the homeland's first rocket plane, the RP-318-1, designed by Korolev. In 1937-1938, ground tests of this rocket plane were conducted using the ORM-65 LPRE. And in 1939-1940, the JPSRI, in conjunction with the Special Design Department (SDD) of the "Aviakhim" [Aviation Chemicals] Plant, conducted flight tests of the RP-318-1 using the RDA-1-150 engine, a modification of the ORM-65. On 28 February 1940, a rocket plane piloted by the SDD test pilot, V.P. Fedorov, was lifted in to the air on a tow line behind the R-5 airplane. Having separated from the tow plane, Fedorov turned on the LPRE at an altitude of 2,600 m. The rocket plane, gathering speed, overtook the aircraft and flew on ahead with confidence.

These tests became a significant event in the history of human flight in rocket-propelled aircraft.

In the JPSRI, they developed and successfully tested in flight the RDD-604 and RAS-5521 rockets designed by L.S. Dushkin. They became the largest LPR's developed and tested in the USSR until the end of 1940.

These rockets had the KRD-600 compound [combined] engine. It was an LPRE, into whose chamber nitrocellulose powder was stuffed. During a launch of the engine, at first the solid fuel is burned. At the same time, the plugs covering the outlet spill ports are burned up. By the end of the combustion of the powder, when the pressure in the combustion chamber was less than that in the tanks with the liquid fuel components -- nitric acid and kerosene, these latter items began to flow into the chamber and the engine shifted from solid-propellant operation to liquid-propellant operation. During the combustion of the powder, the maximum thrust was equal to 3,850 kg. During the LPRE operation phase, the thrust amounted to 1,278 kg.

The RDD-604 rockets had a launch weight of 180-187 kg, including a payload of 30 kg. The fuel tanks system with the solid-propellant gas generator (SPGG)

weighed 52-59 kg. The rocket was launched at an angle of 55 degrees to the horizon using a carriage whose ramp had a length of 8.5 m [19].

In January of 1940, flight tests of 8 RDD-604 rockets took place. The first two rockets, launched on 5 and 9 January, completed successful flights over distances of 17 km and 17.5 km. Particularly successful were the flights completed by rockets nos. 5, 7 and 8, which covered a distance of more than 19 km [19].

The successful flights of five LPR's over distances of 17-20 km represented a significant achievement for Soviet rocket technology on a level with the highest achievements of the world's rocket production of that time.

In 1940-1941, three more series of flight tests were conducted on the 604 rocket. During these tests, the rockets flew over distances of 20 km.

The 521 rocket was intended to be launched both from the ground and from an aircraft. Its design was similar to that of the 604 rocket.

On 6 August 1940, there were flight tests of 5 RAS-521 rockets [20]. They were launched into the air from a plane standing on the ground. In order for them to fly the maximum distance, it was necessary to launch them at an angle of 55 degrees. But, because of the limited dimensions of the firing range, the rockets were launched at an angle of 30 degrees and flew a distance of 11 km. The tests of the rockets reinforced the large successes achieved in the development of rocket production during the testing of the RDD-604 rockets.

STRATOSPHERIC COMMITTEE

After the JPSG became part of the JPSRI, within the Military Science Committee (MSC) of the Central Council of the USSR Osoaviakhim, in January of 1934, they organized a Jet Propulsion Section, which the social activist group of the Moscow JPSG joined. I.A. Merkulov was chosen head of the section and O.S. Oganesov was chosen as his deputy. The active work in the section was carried out by Professors K.L. Bayev, V.P. Vetchinkin, K.A. Putilov, and engineers V.P. Glushko, L.S. Dushkin, G.E. Langemak, A.F. Nistratov, V.N. Prokofyev and M.K. Tikhonravov.

In March of 1934, the Osoaviakhim Central Council, desiring to involve the broad circles of the scientific and technical community in creative participation in the the study and exploration of the stratosphere, organized a Committee for the Study of the Stratosphere, which for short was called the Stratospheric Committee. This committee operated successfully for more than four years. The Jet Propulsion Section became a part of it.

In the Jet Propulsion Section, six rockets were designed, three of which were built. They were the rocket designed by A.I. Polyarnyy using an oxygen-alcohol LPRE, which was originally designated the R-1 and later received the designation "Osoaviakhim," the rocket designed by A.F. Nistratov and I.A. Merkulov (the R-2) with an LPRE operating on a three-component fuel (liquid oxygen, alcohol and water), which was called the three-component rocket -- TR-2, and the ramjet rocket

(the R-3) designed by Merkulov, called the ramjet rocket -- VR-3. The interesting projects developed by Ye. S. Parayev and V.N. Prokofyev for LPR's unfortunately, were not realized. The sixth was a design for a three-stage rocket with an SPRE for all the stages, developed by A.F. Nistratov and received a high evaluation from Professor V.P. Vetchinkin [24].

The Jet Propulsion Section of the Osoaviakhim Central Council was a social scientific organization. Its staff successfully conducted theoretical research, design work, the publication of collected works entitled "Jet Propulsion," and scientific propaganda on rocket technology and cosmonautics. The section trained engineers in rocket technology. But the Osoaviakhim Central Council's Stratospheric Committee did not have its own production base and therefore, the section's developments that were of great interest were handed over to industry for further development. Thus, in 1936, the unit headed up by A.I. Polyarnyy, in its entirety, including all the designers, mechanics and workers, joined the newly organized KB-7 [design bureau].

In 1937, the group of specialists working on the theoretical problems of ramjet engines and on designing ramjet rockets went to the "Aviakhim" Plant, where the designs developed in the Jet Propulsion Section were realized. The standing firing tests of the three-component LPRE rockets, the TR-2, were conducted under the supervision of Nistratov in the ONIL [Joint Scientific Research Laboratory -- JSRL].

"AVIAKHIM"

One more collective of scientists and designers, which conducted work on rocket technology, was organized on the initiative of A. Ya. Shcherbakov, the Special Design Department (SDD) of the "Aviakhim" Plant. The SDD was established to develop a number of interesting inventions in the field of high-altitude aviation, which were produced in the Jet Propulsion Group of the Kharkov Council of Osoaviakhim. The SDD specialists developed the design of the sealed cockpits, which were installed on mass-produced aircraft. They implemented the method proposed by A. Ya. Shcherbakov of high-altitude towing of chains of gliders behind an aircraft.

In 1937, the work on ramjet rockets and aviation ramjet engines was transferred from the Osoaviakhim Central Council, Jet Propulsion Section to the SDD. Sixteen ramjet rockets were built there and in the period from February through May 1939, their flight tests were conducted at the airfield near Planernaya Station outside Moscow. The rockets built at the "Aviakhim" Plant were the world's first ramjet rockets. They were also the first Soviet two-stage rockets.

In the years 1939-1940, the world's first aviation ramjets, designed by Merkulov, the DM-2 and DM-4, were developed and flight-tested at the "Aviakhim" Plant [22]. These engines were installed as auxiliary engines on the I-152 and I-153 aircraft designed by N.N. Polikarpov. For the ground tests and completion of the engines, a special steel wind tunnel, the AT-2, with a length of 12 m and an opera-

tional section diameter of 1 m, was constructed. The official tests of the I-152 aircraft with two DM-2 ramjets were conducted over the Central Airfield M.V. Frunze in Moscow on 25 January 1940. In all, over the period of the flight tests, 74 flights were made. They were carried out by the test pilots P. Ye. Loginov, A.V. Davydov, A.I. Zhukov and N.A. Sapotsko. (The results of the flight test were dealt with in detail in Professor Yu. A. Pobedonostsev's report at the 19th IAF Congress in 1968).

In 1939-1940, the SDD, together with the JPSRI, conducted flight tests on the RP-318-1 rocket plane designed by S.P. Korolev. The chief engineers for these flight tests were A. Ya. Shcherbakov and A.V. Pallo. The tests of the rocket plane were conducted by SDD pilot V.P. Fedorov.

KB-7 DESIGN BUREAU

In 1936, the KB-7 Design Bureau was organized in Moscow to develop LPR's. It was located on Aviation Pereulok, where a well-equipped experimental base had been constructed. The bureau's chief was L.K. Korneyev. His deputy was one of the pupils and closest assistants of F.A. Tsander, the talented scientist and designer A.I. Polyarnyy who was the scientific supervisor of all of KB-7's developments.

KB-7 continued the work on the Osoaviakhim rocket, which retained its own designation there (it was also designated the R-06).

On 11 April 1937, the Osoaviakhim rocket completed its first successful flight [35, p 4]. On 25 August 1937, flight tests for more models took place in Leningrad. These were the first official tests of a Soviet LPR.

The rockets were launched at an angle to the horizon of from 65 degrees to 88 degrees. In each of the launches, the engine operated for 1-18 sec. During the third and fourth launches -- at an angle of 70 degrees and 65 degrees, respectively -- the flight range amounted to 6 km and 5 km, respectively [27, p 11].

In KB-7, five more types of LPR's were constructed. All of them had oxygen-alcohol LPRE's. The design of one of them -- the R-03 -- was begun by L.K. Korneyev, even before the establishment of KB-7. The bureau's staff, under the supervision of A.I. Polyarnyy, developed the design of this rocket in detail, constructed 10 models of it and tested them in April of 1937, together with the R-06 rocket.

For the purpose of seeking methods of ensuring the stability of the rockets in flight, in KB-7 they constructed the R-04 and ANIR-5 LPR's and the R-07m powder rocket.

The R-04 device was a rotating rocket. It was supposed to rotate on the launching carriage at up to 2,000 rpm. Also, in order to have additional rotation during the flight, four powder charges were installed in its nose section.

In 1938, from 25 to 28 February, tests of 6 R-03 and 2 R-06 rockets took place in Pavlograd. In addition, 6 R-07m powder rockets were tested. All the rockets were launched at an angle of 65 degrees or 75 degrees. Four R-06 rockets com-

pleted successful flights at a distance of from 4,000 m (R-03-7) to 6,800 m (R-03-8). The Osoaviakhim R-06 rockets underwent their last flight tests on 28 February, having completed a flight at a distance of 3,100 m [27, pp 60-70].

In the document on the tests of these rockets, the following was stated as a conclusion:

> "It can be stated that KB-7 in its own work with the LP's, developed on the basis of the theory of the Soviet scientist, K.E. Tsiolkovsky, attained significant achievements" ... [27, pp 60-70].

In 1938, six ANIR-5 rockets were prepared in KB-7. In order to increase the flight stability, in accordance with P.I. Ivanov's suggestion, gyroscopes were installed on them which were firmly attached to the body of the rocket. Research on the movement of the rockets with the gyroscopes was conducted by Academician A.N. Krylov. In its own design, the ANIR-5 rocket resembled the R-06 rocket, in which a gyroscope was installed and corresponding changes were made to the stabilizers. Prior to the launch, the gyroscope was rotating at the rate of 19,000 rpm.

Of interest was the R-05 rocket, developed to reach an altitude of 50 km. It was proposed that its stability in flight be ensured by increasing the take-off velocity from the carriage of 40-50 m/s using two launching SPRE's with a total thrust of 1,250 kg/s. The R-05 rocket was intended for the USSR Academy of Sciences' Geophysics Institute, whose director, Academician O. Yu. Schmidt, expressed great interest in it and participated in the discussion of its parameters and instrumentation.

In KB-7, four more LPR designs were developed: the ANIR-6, the ENIR-7, the R-05g and the design for a two-stage R-10 rocket, with a calculated flight altitude of 100 km.

THE "OSOAVIAKHIM" JET PROPULSION GROUP

The development of rocket technology in the USSR was of a broad public nature. In the 1920's and 1930's, in the study of the theory of jet propulsion, its development and first design research on rocket craft included a large number of scientists, inventors, engineers and a particularly large number of interplanetary flight enthusiasts. In 1924, in Moscow, the Society for Interplanetary Communications was formed. In many cities of the Soviet Union, mainly ones with institutions of higher learning, they began to establish groups to study the theory of interplanetary communications. Several of these groups operated successfully over the course of a number of years and from them came the specialists who subsequently became the prominent scientists and designers in the field of rocket technology. For example, in Kharkov in 1925, on the initiative of A. Ya. Shcherbakov, a group of rocket technology enthusiasts was organized at the Kharkov Aviation Institute. This group corresponded with K.E. Tsiolkovsky and carried out successful work on the study of the theoretical bases for rocket technology. A similar group operated successfully under the the supervision of Professor N.A. Rynin in Leningrad. A similar group was organized at the Moscow Aviation Institute under the supervision of F.A. Tsander.

From the beginning of the 1930's, the Osoaviakhim -- a volunteer society and one of whose main tasks was the promotion of the development of aviation -- conducted a lot of work on scientific propaganda on rocket technology and the theory of space flight.

In September 1931, as has already been mentioned above, the JPSG was organized in Moscow within the system of the USSR Osoaviakhim Central Council. In November of the same year, a JPSG (GIRD) was organized within the system of the Leningrad Oblast Council of Osoaviakhim (LenGIRD). Soon after the Moscow and Leningrad groups, JPSG's were organized in many other cities of the Soviet Union. JPSG work was carried out in Kharkov, Gorkiy, Yerevan, Baku, Kiev, Tbilisi, Rostov-on-the-Don and dozens of other cities. Supervision of the activities of all the JPSG's was implemented by the Moscow group headed by S.P. Korolev, which, as of 1932, began to be called the Central [group] -- CJPSG as well.

After the transfer of the CJPSG into the make-up of the JPSRI and the organization in Moscow of the Jet Propulsion Section into the make-up of the Military Science Committee of the Osoaviakhim Central Council, in other cities, within the make-up of the Military Science Committee of the Osoaviakhim, jet propulsion sections or groups were established which continued and developed the work begun in the JPSG's.

The Osoaviakhim jet propulsion sections in the cities of Leningrad, Kharkov and Gorkiy operated the most successfully.

The LenGIRD was headed up by the talented engineer, V.V. Razumov. The staff of the LenGIRD built and tested in flight a number of powder rockets designed by V.V. Razumov with SPRE's designed by V.A. Artemyev and made plans for an LPR based on a design by V.V. Razumov using a rotation LPRE designed by A.N. Shtern, which operated on liquid oxygen and benzene.

After its reorganization and transfer into the make-up of the Leningrad MSC, the Jet Propulsion Section completed the construction of V.V. Razumov's LPR, conducted stand firing tests of its engine and in order to check the rocket's stability, implemented its twisting using an SPRE. Then the Leningrad Jet Propulsion Section, under the supervision of Professor M.V. Machinskiy, designed another series of original LPR's.

Of extreme interest were the activities of the Kharkov JPSG and the Jet Propulsion Section of the Kharkov MSC. A lot of energy in the organization of the work on rocket technology there was expended by A. Ya. Shcherbakov, Professor Dakhov and the young enthusiast, V.I. Rozov. The Kharkov Jet Propulsion Section built a series of powder rockets, tested them in wind tunnels and in flight. Academician G.F. Proskura rendered a great deal of assistance to the Jet Propulsion Section of the Kharkov MSC [21].

The jet propulsion group of the Gorkiy MSC gathered together a large group of scientists, engineers and young inventors.Particularly active in the Gorkiy MSC were Professor K.A. Putilov and the talented inventor, B.R. Pastukhovskiy. In the

Gorkiy MSC, in accordance with a design by engineer Ivanov, they built an original design LPR.

The MSC's in other cities of the USSR conducted propaganda work on the scientific bases of rocket technology and cosmonautics.

A great service of the JPSG's and Osoaviakhim MSC's was the mobilization of broad circles of the scientific, engineering and inventors' communities for the working out of questions on the use of rocket technology to solve pressing problems of that time -- research on the stratosphere and the development of high-altitude aviation, which at the same time were of paramount importance also as the first step on the path to the realization of flights into space.

The brief enumeration listed here of the scientific research and experiment and design organizations, which worked on the development of rockets, speaks of the wide scale which the work in the field of rocket production attained in the 1930's in the USSR. The work of the first scientific centers for rocket technology is a graphic example of how, in the USSR in the first years of the country's industrialization, a successful struggle was carried on for technological progress and for the development of the most advanced and progressive branches of science and technology.

The results of the work of the first Soviet organizations for rocket technology made it possible to draw highly substantial conclusions:

In the 1930's, in the USSR, reliable designs for LPRE's, which operated on a variety of fuels with a high boiling point and cryogenic fuels, were developed.

Over the first decade in the development of Soviet rocket production, rockets of all the well-known types -- single-stage and two-stage, ballistic and winged, ground-launched and air-launched -- were built and tested in flight.

In the USSR, rockets were developed with all the well-known types of jet propulsion engines -- solid-propellant rocket engines (SPRE) and hybrid engines that worked on solid fuel and liquid oxidizers, LPRE's and ramjets.

In 1939-1940, in the USSR, flight tests were conducted on piloted craft with aviation ramjets and LPRE's.

BIBLIOGRAPHY

1. Glushko, V.P., "The Role of the Gas Dynamics Laboratory (GDL) in the Development of Rocket Technology," Vestnik an SSSR, 1972, No 2, pp 100-108.
2. Glushko, V.P., "The Contribution of the Leningrad Gas Dynamics Laboratory (GDL) to the Development of Rocket Technology. Report to the 13th International Congress on the History of Science (Moscow, 1971)," in the collection "Iz istorii aviatsii i kosmonavtiki" [From the History of Aviation and Cosmonautics], Issue 17-18, Moscow, 1972, pp 35-43.
2. Glushko, V.P., "The Development of Liquid-Propellant Rocket Engine Production and its Influence on Science and Technology in the USSR," Vestnik an SSSR, 1973, No 12, pp 110-121.
4. Glushko, V.P., "The Development of Soviet Space Rocket Engine Production," Izvestiya an SSSR, Energetika i Transport [Power Engineering and Transportation], 1974, No 5, pp 3-28.

5. Glushko, V.P., "Raketnyye dvigateli GDL-OKB" [The Rocket Engines of the Gas Dynamics Laboratory's Experimental Design Bureau], Moscow, 1975.

6. Ivanov, N.V., "The First Soviet Rocket Technology Organization," in the book "Idei Tsiolkovskogo i problemy kosmonavtiki" [Tsiolkovsky's Ideas and the Problems of Cosmonautics], Moscow, 1974, pp 67-72.

7. Tikhonravov, M.K., Biryukov, Yu. V., "The Realization of K.E. Tsiolkovsky's Ideas in the Work of the GIRD [Jet Propulsion Study Group]," in the book "Idei Tsiolkovskogo i problemy kosmonavtiki," Moscow, 1974, pp 58-66.

8. Tikhonravov, M.K., "The Role of K.E. Tsiolkovsky in the Development of Rocket and Space Technology. Report to the 13th International Congress on the History of Science (Moscow, 1971)," in the collection "Iz istorii aviatsii i kosmonavtiki," Issue 17-18, Moscow, 1972, pp 186-193.

9. Pobedonostsev, Yu. A., Merkulov, I.A., "The Realization of K.E. Tsiolkovsky's Ideas in the Work of the GIRD," Trudy vi chteniy K.E. Tsiolkovskogo. Sektsiya "Problemy raketnoy i kosmicheskoy tekhniki" [The Problems of Rocket and Space Technology], Moscow, 1973, pp 19-29.

10. Biryukov, Yu. V., "K.E. Tsiolkovsky and the First Steps of Soviet Rocket Production," in the book "Idei Tsiolkovskogo i problemy kosmonavtiki," Moscow, 1974, pp 73-79.

11. Biryukov, Yu. V., Komarov, V.M., "On the Matter of the Organization and Activities of the Jet Propulsion Study Group of the USSR Osoaviakhim Central Council," in the collection "Iz istorii aviatsii i kosmonavtiki," 1974, Issue 24, pp 52-81.

12. Pobedonostsev, Yu. A., Merkulov, I.A., "On the 40th Anniversary of the Moscow Jet Propulsion Study Group (GIRD [JPSG])," in the collection "Iz istorii aviatsii i kosmonavtiki," Issue 24, Moscow, 1974, pp 8-16.

13. Raushenbakh, B.V., Biryukov, Yu. V., "JPSG Chief S.P. Korolev -- the Founder of Practical Cosmonautics," in the collection "Iz istorii aviasii i kosmonavtiki," Issue 24, Moscow, 1974, pp 17-24.

14. Korolev, S.P., "The Flight of Jet Propulsion Craft in the Stratosphere," Trudy vsesoyuznoy konferentsii po izucheniyu stratosfery, Leningrad-Moscow, 1935, pp 849-855.

15. Korolev, S.P., "Winged Rockets and Their Use for Manned Flight," in the book "Pionery raketnoy tekhniki. [The Pioneers of Rocket Technology] Vetchinkin, Glushko, Korolev, Tikhonravov," Moscow, 1972, pp 452-475.

16. Sokolskiy, V.N., "A Concise Outline of the Development of Rocket Technology (up to the End of the Second World War)," in the collection "Iz istorii aviatsii i kosmonavtiki," Issue 26, Moscow, 1975, pp 113-144.

17. Arkhiv an SSSR [Archives of the USSR Academy of Sciences], Sec. 4, Cat. 14, D. 50.

18. Ibid, D. 53

19. Ibid, D. 75.

20. Ibid, D. 78.

21. Ibid, D. 213.

22. Shcherbakov, A. Ya., "Ramjet Flight Tests on Planes Designed by N.N. Polikarpov in 1939-1940," in the collection "Iz istorii aviatsii i kosmonavtiki," Issues 3, Moscow, 1965, pp 40-49.

23. Merkulov, I.A., "The Realization of K.E. Tsiolkovsky's Ideas in the First Soviet Rockets," Trudy x chteniy K.E. Tsiolkovskogo. Sektsiya "Problemy raketnoy i kosmicheskoy tekhniki," Moscow, 1977.

24. Merkulov, I.A., Nistratov, A.F., Romanenko, B.N., "The Realization of K.E. Tsiolkovsky's Ideas in the Work of the Osoaviakhim Central Council's Jet Propulsion Section," Trudy ix chteniy K.E. Tsiolkovskogo. Sektsiya "Problemy raketnoy i kosmicheskoy tekhniki, Moscow, 1975, pp 147-155.

25. Tsentralnyy arkhiv dosaaf SSSR. Prikazy po lichnomu sostavu. Otdel vozdushnogo flota. Prikaz po tss Osoaviakhima ot 14 iyulya 1932 G. [The Central Archives of the USSR Voluntary Society for the Promotion of the Army, Air Force and Navy. Orders Regarding Personnel. The Air Force Department. The Order Regarding the Osoaviakhim Central Council of 14 July 1932].

26. Merkulov, I.A., "The First Experimental Research on JPSG Ramjets," in the Collection "Iz istorii aviatsii i kosmonavtiki," Issue 3, Moscow, 1965, pp 22-32.

27. Arkhiv an SSSR, op. cit., D. 61.

28. Ibid, D. 59.

29. Komarov, V.M., Sadovoy, G.A., "On the Influence of K.E. Tsiolkovsky's Ideas on the Development of the Rocket Technology Enthusiasts Movement in the USSR (the '20's and '30's)," Trudy v chteniy K.E. Tsiolkovskogo. Sektsiya "Problemy raketnoy i kosmicheskoy tekhniki," Moscow, 1971, pp 95-108.