（№3　2001年1月1日号目次）

航空宇宙関連研究開発機関（その1）

今号から３回にわたり、ロシアの航空宇宙関連の研究開発機関を特集します。

この分野は規模も大きく、興味深い技術開発が数多く行われています。

ロシアにおける宇宙部門の国家管理

現在のロシアにおける宇宙開発に対する国家管理体制は、1992 年の大統領令よるものである。専門の部署として「宇宙庁」が設立され、1999 年に航空宇宙庁（Russian Aviation and Space Agency – Rosaviakosmos)と改組された。

その他の管理機構として重要なのは旧ロケット部隊、現在の国防省傘下の戦略ミサイル軍 である。

さらに、大統領、議会（上下院）、政府、そして省庁がそれぞれの責任の範囲で宇宙開発の管理に関与している。

分担としては大統領が大きな問題の決定、議会は規範作り、政府は当面の問題の処理である。通常は Rosaviakosmos または国防省から提案がなされて、それに対応する形である。

他にも宇宙開発に関わっているのは宇宙問題省庁間専門委員会、ロシア科学アカデミー宇宙委員会、大統領府技術委員会等があるが、これらの機関は意志決定ではなく、上記の管理機構に提言を行う。

しかし、ロシア科学アカデミーは公的組織として、宇宙開発に特別な役割を果たしている。すなわち、宇宙に関する基礎研究と連邦宇宙計画策定への参加である。科学アカデミー宇宙委員会は立法および行政機関と連絡を取り、国際協力を調整する。Rosaviakosmos とともに、ロケットや宇宙船、あるいは宇宙全般に関する問題を検討し、宇宙に関する基礎研究の方向性を定める。

宇宙委員会の委員長はオシポフ・ロシア科学アカデミー総裁であり、科学アカデミー、産業科学技術省、天然資源省、外務省の代表から成る 60 名の委員により構成される。宇宙委員会には 10 の部局がある。

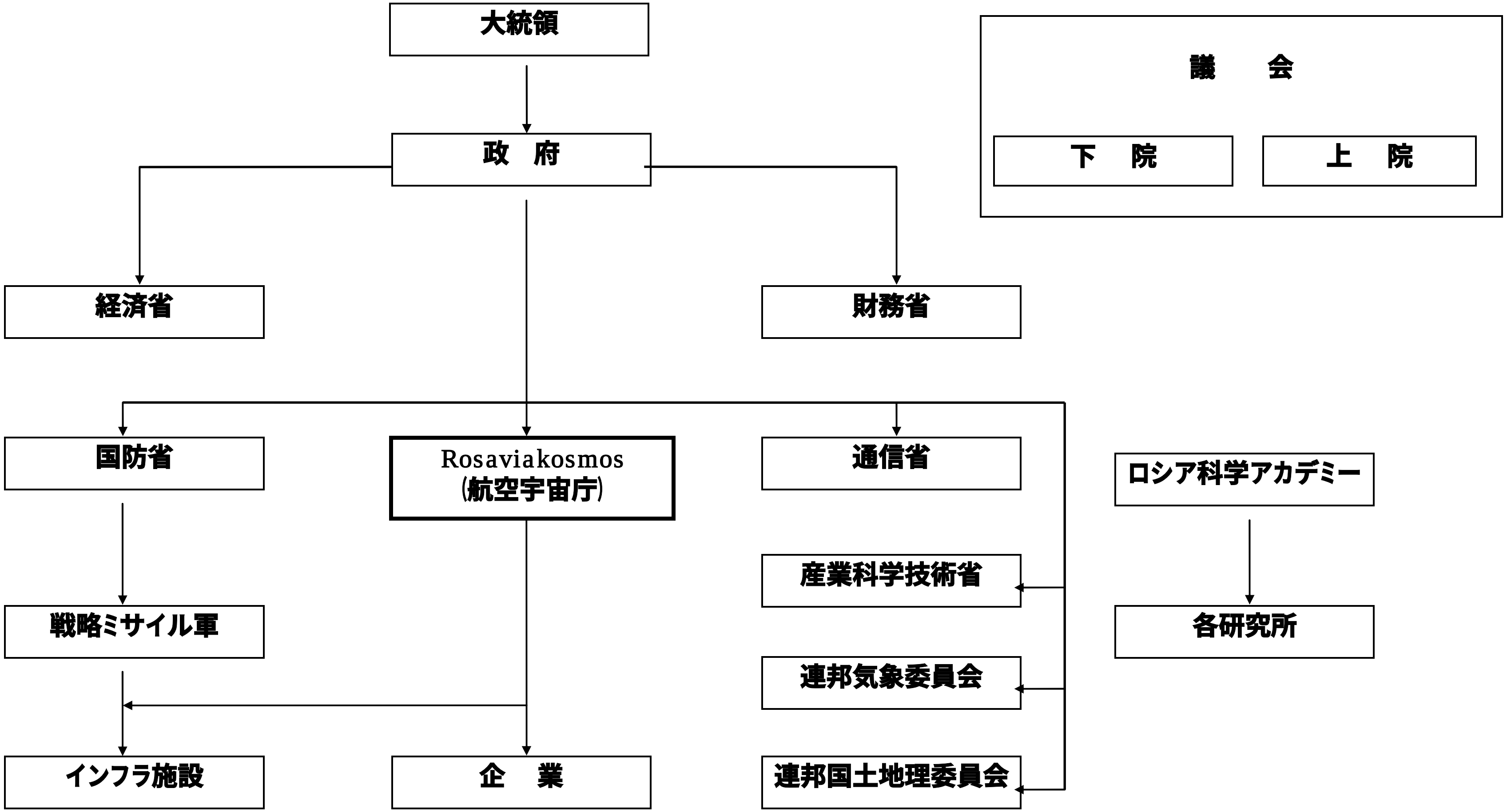
- 宇宙プラズマ物理学と太陽ー地球の関係（責任者 V.N.オラエフスキー、科学アカデミー地磁気・イオン層・電波伝達研究所）
- 太陽系の惑星と小惑星（A.A.ガレーエフ・アカデミー会員、科学アカデミー宇宙研究所）
- 大気圏外天文学（A.A.ボヤルチュク・アカデミー会員、科学アカデミー天文学研究所）
- 宇宙線（M.I.パナスーク、モスクワ国立大学核物理学研究所）
- 宇宙生物学、医学（A.I.グリゴリエフ・アカデミー会員、生医学研究所）
- 宇宙材料（Yu.A.オシピャン・アカデミー会員）
- 宇宙からの地球観測（N.P.ラヴェロフ・アカデミー会員）
- 宇宙飛行の基礎研究（V.Ya.ネイランド・アカデミー準会員）
- 宇宙調査の法的、社会経済的諸問題（N.I.コムコフ、科学アカデミー経済予測研究所）

・　国際協力（V.A.コテリニコフ・アカデミー会員）

委員会の第一副委員長はボヤルチュクとラヴェロフで、副委員長はコテリニコフである。委員会の事務局は科学アカデミー宇宙局で、その代表は A.V.アルフォーロフ学術書記である。

ロシアの宇宙開発を定める基本文書としては 1993 年 12 月 11 日付け政府決定№1282 により承認された連邦宇宙計画である。その後、Rosaviakosmos により同計画の変更と追加がなされ、政府に承認された。

ロシアにおける宇宙部門の国家管理組織図



ROSAVIAKOSMOS 組織図

- **総　裁 – Yu.N. コプチェフ**
  Tel.: 288-9905, 971-8021
  - 科学技術会議
  - 理事会
    19 人
  - 国家書記兼第一副総裁
    V.V. アラヴェルドフ
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    Tel.: 971-9172, 975-4736
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    Tel. 971-6936, 971-9660
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  - 副総裁
    A.N. メドヴェチコフ
    Tel. 975-4167, 971-9176
  - プロジェクト遂行支援部
    B.M.ズィメンコフ
    Tel. 288-9922, 971-9230
  - 国際部
    V.K.マカロフ
    Tel. 971-9737, 975-4406
  - 安全保障部
    B.I.フィノゲノフ
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  - 総務部
    F.D.デニーソフ
    Tel. 971-9393
  - 人事・広報部
    V.V.セミョーノフ
    Tel. 975-4502, 971-8481

①企業「エネルギヤ」
(モスクワ州カリーニングラード市)

I. Name of the Institute (Organization)

In Russian: Ракетно-космическая корпорация «Энергия» им.С.П.Королева

In Russian abbreviation: РКК “Энергия” им.С.П.Королева

In English: Korolev Rocket Space Corporatopn “Energia”

In English Abbreviation: RSC “Energia”

II. Location

Official address: 4a Lenin Street, Korolev, Moscow Region, 141070, Russia

Mail address: 4a Lenin Street, Korolev, Moscow Region, 141070, Russia

Telephone number: (095) 513-7703

Fax number: (095) 187-9877, 513-8620

E-mail for representative: mail@rsce.ru

Website: http://www.energia.ru

Access (transportation, necessary time): Moscow international airport Sheremetjevo-2, one hour by car. RSC “Energia” is located 10 kilometers away from Moscow.

III. History

From the moment it was founded to the present day, our organization - which was successively known under the names of Special Design Bureau number 1(SDB-1)/TsKBEM/NPO Energia/S.P.Korolev RSC Energia - has been successfully carrying out the most daring rocket and space projects requiring revolutionary engineering solutions. The organization has been changing its name, while preserving and increasing both its production capacity and intellectual resources. Today's powerful scientific and engineering potential of S.P.Korolev RSC Energia allows it to work on the projects of the highest level of complexity.

The history of S.P.Korolev Rocket and Space Corporation is the story of the company and its people, who, in the most difficult years that came after the end of World War II, and then, in the tense years of the Cold War, were destined to become pioneers in rocket and space technology, create a new type of weapon which assured the parity between the two opposing military and political alignments, and, for many decades, retain a leading position in the most advanced and science-intensive area of human endeavor in the twentieth century - the space science.

The story of the pioneering days of the Russian rocket and space technology is a story of people and their deeds, the people who were united in their desire to protect their country and save mankind from self-destruction in a nuclear war. It is more than fifty years now since the day when our company was founded and gave birth to the rocket and space industry. In its early formative days, getting ahead of its time and outstripping the existing level of technology, it made possible a speedy development of the most efficient system for delivering nuclear weapons to their targets, which became the basis for creating the weapon of deterrence - the nuclear and missile shield of our country. Rapid development and improvement of this weapon made the countries in possession of such a weapon to look for mutually acceptable compromises and opened for the mankind the door to the study and exploration of the infinite expanses of the Universe. In the designers' rooms, on the shop floors, in the offices of the management of the Special Design Bureau number 1 - now known as S.P.Korolev Rocket and Space Corporation Energia - a new area of human endeavor - the study and exploration of space as a new environment for human habitation - was being born.

Foundations of the company were laid by S.P.Korolev. Over the course of two decades, his most important contribution consisted in his ability to transfuse his desire to fathom the unknown to thousands of people who were working with him, to continuously confront his team with creative challenges. He knew how to arrive to a trade-off decision to solve a problem, and to direct his team's efforts to the solution of those problems that were the most critical at that moment.

At different times, the company was headed by Chief (General) Designers for the rocket and space technology - S.P.Korolev, V.P.Mishin, V.P.Glushko, Yu.P.Semenov, while its Experimental Machine-Building Plant was headed by P.I.Maloletov, F.P.Gerasimov, R.A.Turkov, V.M.Klucharev, A.A.Borisenko, A.F.Strekalov. Always at their side have been their associates, a team of scientists, engineers, workers, with state-of-the-art skills, who are united in their complete dedication to their work, their constant focus on the search for the most practical solutions, systems approach in analyzing development trends, both in the rocket and space technology as a whole and in specialized problems that have to be addressed in order to further its development.

High level of each employee's professionalism coupled with the principle of joint decision-making became the rule guiding the operation of our company, and assured the success of the efforts to develop highly complex rocket and space technology, which made it possible for our country to remain the leader in manned spaceflight for many years.

Pride of place in the history of space science in our country is held by the R-7 rocket design effort. This rocket, originally developed at a short notice as a vehicle for delivering a nuclear warhead to any point on the globe, became a starting point for a long line of launch vehicle modifications that are still being used for putting into space manned spacecraft and spacecraft for various applications. The Special Design Bureau Number One, the organization which started the missiles industry and has been continuously building up its intellectual, technological and production potential, happened to be chosen by History to become the pioneer in virtually all the fields of space industry in our country, as well as to play a leading role in bringing into being and developing the world's space science.

The reorientation of the Special Design Bureau Number One towards space science was initiated by an S.P.Korolev's memo "On the Earth's Artificial Satellite" submitted to the Government in May 1954. The launch by our country of the Earth's first artificial satellite on October 4, 1957, ushered in the Space Age in mankind's history. After that event, the Special Design Bureau Number One and its subcontractors began living on a compressed time-scale. While the world was still astounded by the launch of the Earth's first artificial satellite, the company, concurrently with development of missiles, speeded up its work on the interplanetary probes for the study of near and deep space, the Moon, planets of the Solar System, on unmanned spacecraft for observing Earth's surface, and on space communications system based on Molniya satellites. All this work was being done along with addressing complex scientific, technological and logistical problems attendant upon the formation of new production facilities and providing support for the launch of a manned spacecraft.

April 12, 1961 became the day of triumph for the Human Mind. For the first time in history, a man-made vehicle with a human onboard emerged into the expanses of the Universe; for the first time in history, a human voice was heard from space, a voice of a citizen of planet Earth, our compatriot, Yuri Gagarin. It was a real exploit on the part of all the participants in this work.

At the same time, on the initiative of S.P.Korolev, an infrastructure was being established and developed for the newest branch of the domestic industry - the rocket and space industry which, in the ensuing years, was to become one of the most advanced and promising fields of science-intensive technologies. A characteristic feature of that phase was the creation in our country of companies specializing in individual fields of space science, which originated within the walls of the Special Design Bureau Number One, and then evolved into independent organizations. Later on, they became the prime organizations for those fields (missiles systems, communications systems, observation systems, etc.) and developed rocket and space systems that were at least on a par with the world's best technology, and in many cases even ahead of it.

The development of rocket and space technology made it necessary to improve the governmental management structures in our country. In 1960, within the organizational structure of the Ministry of Defense, a new branch of military service, Strategic Missiles, was established, from which Military Space Force later emerged as a separate branch. In 1965 the Ministry of General Machine-building was established.

Paralleling this, both in time and from the standpoint of the tasks addressed, was the development of the rocket and space technology in the United States, with the work in both countries being a competition in the implementation of space research programs using manned and unmanned systems and spacecraft.

The spirit of confrontation existing between the two superpowers resulted in the USSR and USA embarking on their independent hugely expensive projects to land a man on the Moon.

That competition, besides achieving political goals, has enriched scientific and technological knowledge. Science has acquired reliable information about the Moon and its surface as a result of studies of the materials brought back by US astronauts and data obtained from our country's unmanned spacecraft, while industry has developed new technologies.

Upon completion of that work, the scientists and designers were faced with a problem of defining what lines of the manned spaceflight development should be further pursued. The USSR chose to develop manned space stations and their transportation and logistics support, while the USA gave the priority to the development of a reusable manned transportation spacecraft.

Common interests in space made the heads of the two countries abandon their political ambitions and start working on the joint Soviet-American project Soyuz-Apollo. Its implementation was a success. Scientists and engineers of both countries have compared the levels of their achievements in the development of space systems, while politicians have displayed signs of the two superpowers' mutual respect towards each other.

Unfortunately, that union proved to be short-lived. The spirit of competition re-emerged. To demonstrate engineering and technological capabilities of our country, a decision was made to build a domestic reusable space system that would be capable of at least as good a performance as its US analog. Aggressive schedules, the need to coordinate a large number of disparate companies, the novelty and complexity of the design effort required a suitably extraordinary approach.

In our country, at that time, NPO Energia was the only company in space industry which had experience in the development of gigantic projects that were unique in their complexity, and possessed the necessary scientific and technological potential, and that was why the prime overall responsibility for the project was given to our company. Despite the fact that the work on that project started later than in the USA, and the scientific, technological and logistical problems that had to be addressed were enormous, our company, together with its numerous subcontractors (amounting to more than 1200 organizations), has accomplished this task. A reusable orbiter Buran was built and, in the course of its first unmanned flight, performed, for the first time in history, an automatic landing of a spacecraft of that class. The capabilities of the Energia-Buran space transportation system were many years in advance of its time, while some of its performance characteristics were higher than those of the reusable Space Shuttle system currently operated by the US.

All the development work on the reusable space system Buran at our company was being done concurrently with the operation of space stations Salyut, development and the initial phase of deployment of Mir space station, which also required selflessness and complete dedication to work from our employees.

The path traveled in the exploration of space cannot be measured in either the depth of theoretical studies, or the number of rockets launched, or the exultation of witnesses of space flights. Only by visualizing the entire path that the mankind had to travel to reach space, the wide variety of scientific, technological and logistical problems that had to be addressed, and by reconstructing the drama of ideas and the roles of personalities, can one truly realize the greatness of this feat of science and the importance of the scientific mission of the people who opened up a new line in the civilization's historical development - the practical utilization of space to benefit life on Earth.

The development of the space science required participation of hundreds of thousands people, hundreds and thousands of institutes, design offices and factories, their close cooperation and coordination. A team effort to develop launch vehicles and spacecraft implies not only the search for a solution to scientific, technological and logistical problems, but also hard, dedicated and selfless labor of their creators who turn individual concepts, ideas and drawings into faultlessly operating structures, equipment and systems; it implies a highest degree of responsibility of the management and engineering staff for working out and adopting specific technical solutions.

Although not all of the things that were originally envisioned have been achieved, the space communications and TV, and the monitoring of weather and the Earth's surface from space have become an integral and essential part of our everyday life. No further advances of mankind in the search for the most efficient areas of space exploration and utilization can be possible without a well-rounded development of space science, and manned space programs are playing a decisive role in this process. The logic of international development of space science has unavoidably led Russia and USA towards cooperation in the development of a new-generation of manned space stations in the name of advancing scientific and technological progress and supporting man's activity in space. Both countries consider cooperation in this field as one of the most important areas that serve the interests of both Russia and USA, as well as the entire world community.

The mankind is given a chance to pool its efforts in space research and exploration to the benefit of the entire Earth's civilization. Such pooling of efforts will allow to implement not only the International Space Station development plan currently under way, but also a more ambitious project of putting a man on the surface of planet Mars as early as the first decade of the next, twenty first, century!

IV. Management

Kind of organization: Public Limited Corporation
Ownership: Russian Aviation and Space Agency

V. Executives

Yu.P. Semenov - Corporation President, General Designer,
Head of Prime Design Bureau
N.I. Zelenschikov - Corporation First Vice-President,
First Deputy General Designer, First Deputy Head of Prime Design Bureau
A. F. Strekalov - Corporation First Vice-President,
Director of ZAO Experimental Machinebuilding Plant
A. L. Martynovsky - Corporation First Vice-President,
Deputy Head of Prime Design Bureau
V.P.Legostaev - Corporation Vice-President, First Deputy General Designer,
Deputy Head of Prime Design Bureau
A. F. Kozeeva - Corporation Vice-President,
Head of Financial and Economic Department
N.I.Chekin - Corporation Vice-President

VI. Current major activities

Orbital Space Station “Mir”

- X-ray observation of Super Nova 1987 A outburst in Large Magellanic Cloud;
- ecological Earth monitoring by the Priroda science hardware;
- radio probing of Earth ionosphere in the interests of the Russian ionosphere-magnetic service;
- recording of bursts of charged particles being a prophet of earthquakes
- semi-industrial production of new materials, crystals and alloys under micro-gravity conditions in dedicated high-temperature Krater, Gallar, Optison and Queld furnaces;
- production of super-pure biologicals and drugs (insulin, interferon, anti-influenza serum, etc.), a new branch of space medicine was created in medical science

Long-term exposure (up to 10 years) of structural materials on the Station external surface;

- investigation of low-temperature plasma in micro-gravity conditions on the Plasma Crystal facility;
- validation of large structures deployment process (Sofora, Rapana and Strombus experiments), super-light antennas and film reflectors (Znamya and Reflector);
- development test of communication facilities;
- spectrometric and radiometric investigations of space background;
- development test of the closed-loop processing system for on-board production of the crew life support consumables (water, oxygen, food products);
- test of the unique crew performance maintenance system for long-duration flights (up to 1.5 years).

Sea Launch –Sea-Based Space Rocket Launch System

S.P.Korolev RSC Energia has previous experience in developing sea-based rockets. The first launch at sea of a missile R-11FM, which was developed at this company, was carried out on September 16, 1955 in White Sea from a B-67 submarine floating on the surface. Its role in the project is the prime integrator of the rocket segment, the development of which involved more than 30 Russian companies, as well as Ukrainian companies. The corporation developed and mass-produces upper stage Block DM-SL, provided support for the development of automatic systems controlling pre-launch processing and launch, a system for controlling the flight of the upper stage, the measuring complex, systems for filling the upper stage with high-boiling propellant components and gases, the upper stage testing and mechanical ground support equipment, and is also responsible for their operation.
RSC “Energia” participates in development of Angara heavy launch vehicle, led by Khrunichev Center (RSC “Energia” is responsible for the 2nd stage).

RSC “Energia” is the major Russian participant in the International Space Station Project. In the framework of this Project RSC “Energia” is developing thechnical documentation on experimental components and facilities necessary for terrestrial development of the Scientific Energy Platform (SEP). At the test rigs belonging to RSC “Energia” and ZEM is being performed experimental work with Docking Unit (DU-1) and fabrication of its flight module.
RSC “Energia” is also developing and fabricating an Universal Docking Module for ISS.
RSC “Energia” is involved in developing a percpective rocket-space complex “Yamal” and also a space-oriented aviation-rocket complex “Air Launch”.

VII. Number of employee

25000

VIII. Major facilities

Test facilities RSC “Energia” possesses:

- facilities for simulation and evaluation of guidance and control systems;
- envirinmental test facilities;
- facilities for development of liquid metal and refactory material systems;
- thermal vacuum chambers;
- vibration test equipment;
- shock test equipment;
- static load test equipment;
- high temperature test installations;
- test facilities for pyrotechnic devices;
- installations for testing of antennas and antenna feed instruments;
- test stands for liquid propellant engines.

IX. Commercial proposals

- development of highly complex space systems and assemblies for scientific and applied missions (manned space stations and transportation systems);
- development of space station modules for scientific, manufacturing technological and ecological purposes;
- development of universal orbital platforms;
- development of expandable and reusable space transportation systems, heavy and super-heavy launch vehicles, and orbital transfer vehicles;
- development and production of spacecraft for telecommunications and broadcasting on the basis of integrated satellite systems;
- development and production of liquid propellant engines for upper stages;
- development and production of monopropellant thrusters;
- development and propuction of spacecraft components, including docking systems, guidance and control equipment, etc.

② 中央空力学研究所
(モスクワ州ジュコフスキー)

I. Name of the Institute (Organization)

In Russian: Государственный научный центр Российской Федерации Центральный аэрогидродинамический институт им. профессора Н.Е. Жуковского

In Russian abbreviation: ГНЦ РФ ЦАГИ

In English: State Research Center of Russian Federation - Professor Zhukovsky Central Aerohydrodynamic Institute

In English Abbreviation: SRC - TsAGI

II. Location

Official address: 1 Zhukovsky st, TsAGI, Zhukovsky, Moscow Reg., 140160, Russia

Mail address: 1 Zhukovsky st, TsAGI, Zhukovsky, Moscow Reg., 140160, Russia

Telephone number: (095) 556-41-79, 556-40-21, 556-40-00

Fax number: : (095) 911 00 19, 556 43 371

E-mail for representative: slc@tsagi.ru; slc@tsagi.rssi.ru

Web-site: http://www.tsagi.ru

Access (transportation, necessary time): Moscow international airport Sheremetjevo-2, two hours by car

III. History

The Central Aerohydrodynamic Institute was founded on December 1, 1918 on the initiative and under the leadership of N.E.Zhukovsky, the father of the Russian Aviation. Today's TsAGI is the largest scientific research center in the world. Under the Russian Federation Government Decree No.247 of March 29, 1994 TsAGI was conferred a status of the State Research Center.

It was for the first time that a scientific institution combined the basic studies, the applied research, the structural design, the pilot production, and testing. TsAGI developed new aerodynamic configurations, aircraft stability/controllability criteria, strength requirements, the theory of flutter, and many other basic and applied options in both theory and experimental studies.

During the last two decades TsAGI has reached significant advances in Aerodynamics, Flight dynamics and Flight control systems as well as statical material strength, service life and reliability of civil airplanes. Methods for structural analyses and optimization make it possible to reliably design the new-generation aircraft so as to ensure a 50000-60000 hour service life.

These results were used while developing Tu-204 (by General Designer A.A.Tupolev) and Il-96-300 (by General Designer G.V.Novozhilov).

In 1980s the TsAGI's scientists worked on improving agility of up-to-date fighters. Solutions have been obtained for many problems on control of airplanes under flow separation conditions at high incidence. This is evidenced by fair agility of MiG-29 (by General Designer R.A.Belyakov) and Su-27 (by General Designer M.P.Simonov) and has been shown by performing the "Cobra of Pugachyov" maneuver.

When preparing "Energia" launcher and "Buran" reusable aerospaceplane, TsAGI has made considerable investigation into aero/gasdynamics, flight dynamics and structural strength for velocities ranging from the orbital ones to the landing ones. There were challenges of hypersonic flight physics, control systems for the wide range of velocities, mathematical modeling of numerous processes, and a study of motion on flight simulators.

IV. Management

Kind of organization: State Research Center of Russian Federation

Ownership: State property of RF

V. Executives

Vladimir G.Dmitriev - Director

Sergei L. Chernyshev - Deputy Director

Vladimir M.Tyurin - Consultant of Director

Yuri N.Ermak - Deputy Director

Gennadi A.Pavlovets - Deputy Director

Valeri L.Sukhanov - Deputy Director

Evgeni S.Vozhdaev - Deputy Director

Anatoli G.Munin - Deputy Director

Vasili P.Rukavets - Deputy Director

Yuri A.Stuchalkin - Deputy Director

Leonid M.Shkadov - Deputy Director

Olga A.Bessolova - Deputy Director

Mikhail S.Korenev - Deputy Director

Minnkhat N.Mirgazov - Chief of Engineering Services

Olga S.Chicherova - Deputy Director

Vyacheslav G.Pavlov - Deputy Director

VI. Current major activities

The Directions of Research Activities:

- concept definition and choice of reasonable parameters;
- design of aerodynamic configurations and control systems;
- wind tunnel tests in combination with a set of physical studies;
- design and fabrication of wind-tunnel models and testing of propellers and profanes;
- studies on structural concepts in compliance with static/fatigue strength and/or aeroelasticity constraints;
- development of software to Customer's specifications, analysis of general and local strength by using state-of-the-art techniques and programs;
- static and fatigue testing of airframes in combination with nonuniform heating;
- elaboration, fabrication, and installation of automatic control systems and data acquisition systems;
- analytical and experimental research of phenomena of aeroelasticity and structure dynamic behavior;
- elaboration and fabrication of test support equipment for vibration-resistance tests and for flutter tests in wind tunnels;
- options for advanced test benches to be used in aerodynamic, aerothermodynamics, flight dynamics and material strength;
- experiments on flight simulators;
- concepts of flight control systems, creation of modern digital airborne computer-based control systems;
- development and modernization of terrestrial transport means, small scale aviation and aviation for general purposes;
- introducing of air&space technologies into civil industries;
- commercial aerodynamics, including wind energy installation, fans etc.;
- development and manufacture of equipment & production lines for composite materials;
- R&D in the field of ecology and health protection.

VII. Number of employee

2200

VIII. Major facilities.

The unique CAHI experimental base consist of:

- complex of different dimension wind tunnels and gasdynamics facilities with subsonic, transonic, supersonic and hypersonic flow speeds:

• large wind tunnels with open working cross section (T-101, T-102, T-103, T-104, T-105) used for precising of flying objects characteristics at low speed. The largest (T-101) has elliptical cross section 24m x14 m;

• subsonic and transonic wind tunnel (T-106) with continuous flow having working cross section 2.5 m with Mach from 0.05 to 1.15;

• subsonic, transonic and supersonic blast wind tunnel T-109.

Design and Operating Principle

The subsonic, transonic and supersonic speed wind tunnel T-109 is an intermittent semi-closed return-circuit wind tunnel with two injectors and a supersonic variable diffuser. The flow in the wind tunnel is built up by compressed air being accumulated in bottles by compressors. One test may take 10 to 15 minutes. The wind tunnel has a 2.25x2.25 m closed squire test section, 5.5 m long. Horizontal and vertical walls may be solid as well as perforated. The horizontal wall perforation percentage ranges from 0 to 18%, the vertical walls are partially perforated.

The wind tunnel is equipped with three types of suspensions: a sting, a three-point strip suspension of model, a lateral sting. The wind tunnel is provided with a constant-geometry nozzle set and a controllable nozzle (M=0.4 to 4.0). The wind tunnel has a unit simulating jet efflux by compressed air outflow and a unit simulating the operation of the air-jet engines with the use of special engine simulators (air-jet engine, turboprop engine, turbojet engine). The wind tunnel has automated suspensions with remote control to study the process of stores separation.

Technical Performances:

- Mach number	$0.4 \le M \le 4.0$
- Reynolds number Re (l=1m)	$12 \cdot 10^6 \le Re \le 50 \cdot 10^6$
- dynamic pressure (q)	up to 70000 Pa
- model dimension	
length	up to 3.0 m
span	up to 1.5 m
- angles of attack	$-5° \le \alpha \le 20°$
- angles of yaw	$-10° \le \beta \le 10°$

• continuous flow transonic wind tunnel T-128 having working cross section 2.75x2.75 m with Mach from 0.15 to 1.7;

• supersonic and hypersonic wind tunnels T-116 and T-117 having working cross section 1.0x1.0 m and Mach 1.75÷10.0 (T-116) and 10.0÷20.0 (T-117);

• complex of movable (and stationary) pilotage stands and stands for control systems;

• complex of stands for research of static and dynamic durability, endurance, aeroelasticity, thermal and acoustic durability of real flying objects and their components;

• stands for tests jet inlets and nozzles;

• complex of stands for aviation acoustics:

• acoustic reverberation chamber PK-1500 (9x11x14 m) for tests of durability and fatigue characteristics of various structure components under impact of acoustic field (163 dB) of high intensity in a wide frequency range (20-2000 Hz).

• CK-5 acoustic test stand

The stand is intended to investigate different types of compressors (models) for operating noise and efficiency of the noise suppressers (materials) used.

<u>Specifications</u>

Chamber length - 9.4 m Chamber width - 6.65 m Chamber height - 3.6 m

Chamber volume - 240 m^3 Chamber area - 62.5 m^2

Drive nominal power - 2800 kW Drive nominal speed - 20000rpm

Air flow rate - to 45 kg/s Maximum drive torque - 175 kgf m

Inlet air conditions - atmospheric

• CK-4 compressor test stand

The stand is intended for testing real compressors of the axial and radial flow type.

<u>Specifications</u>

Test section diameter	- 2.5 m
Test section length	- 4.0 m
Drive power	- 6250 kW
Drive speed	- 12000 prm, max
Drive sense of rotation	- left and right
Reduction air flow (main duct)	- 250 kg/s, max
Reduction air flow (by-pass duct)	- 40 kg/s, max
Compressor inlet pressure	- (0.133 to 2.0) 10^5 Pa
Compressor inlet temperature	- 293÷298 K

• hydrodynamic stands;

• test equipment:

• thermal vacuum chamber ТПВК-1 (diameter - 14 m, length - 30 m) for durability tests of hypersonic and air-space objects under impact of nonhomogenious thermal field, low frequent mechanical loads and low pressure of environment (T=120÷1750K, P=10000 кН).

IX. Commercial proposals

TsAGI offers a wide array of expertise, equipment, analytical as well as experimental methods and production techniques:

- concept definition and choice of reasonable parameters of aircrafts and engines; render qualified consultation;
- design of aerodynamic configurations, control systems, engines;
- carry out a complete cycle of designing of aerodynamic and gasdynamic plants;
- customize design for a test facility for field investigations of strength and acoustics, relying on TsAGI's long-term engineering experience and collective specialities;
- develop, design and manufacture a small series of special sensors, measuring or other special-purpose test equipment.
- wind tunnel tests in combination with a set of complex physical studies;
- design and fabrication of wind-tunnel test models;
- testing of propellers and propfans;
- studies of structural concepts in compliance with static/fatigue strength and/or aeroelasticity constraints;
- development of software to customized specifications and state of the art strength analysis;
    - data acquisition and processing systems ;
    - multi-component force sensors;
    - transducers of pressure, deformation, heat fluxes, surface friction and temperatures;
    - sensors of total and static pressure and stagnation temperature of gas flows;
    - systems for measurements of three-dimensional deformations of complex structures;
    - optical and physical methods of flow visualization, method of luminescence pressure transducers;
    - metrological support of measurements.
- development of New Trends in the Field of Dual Technology;

    TsAGI develops and produces these devices for sale:

    - thermal converters with the protective accessories for objects of heat-and-power engineering, machine-building, food industry, etc
    - weight measuring devices and systems for automation of technological processes
    - strain-gauge resistors for measurement of deformations and definition of structure service life
- static strength and fatigue testing of airframes under variable conditions of heat and pressure;
    - aircraft and spacecraft;
    - advanced high-technology transportation systems;

- high-rise buildings and constructions, underground communications;

- analytical and experimental research of phenomena of aeroelasticity and structural dynamics;
- development of requirements for aircraft stability, controllability and control systems;
- experimental investigation of aircraft dynamics using flight simulators and with test pilots;
- development of new methods of partial full-scale flight simulation;
- development and creation of experimental facilities.
- creation of test support equipment for vibration-resistance tests and for flutter tests in wind tunnels;
- developing advanced equipment for testing aerodynamics, aerothermodynamics, flight dynamics and material strength;
- experiments on flight simulators, in wind tunnels and test installations;
- concepts of flight control systems; creation of modern digital airborne computer-based control systems, etc.

Conversion projects/proposals of TsAGI:

- organizing manufacture of automatically controlled electric furnaces;
- organizing manufacture of irregular tooling (moulds, press tools, models) of high precision for machine-building;
- organizing manufacture of high-pressure polyurethane foam casting machines, complexes for applying polyurethane foam in moulds;
- development of energy-saving process for carbon black production;
- design and manufacture of prototype device for removing explosive vapors from tanks by using the low-pressure gas ejectors;
- implementation of novel elements for machinery and buildings: reinforced elastomeric panels (REP);
- preparation of prototype designs of free-stream water-power stations for plain rivers;
- development of flying laboratory on the basis of Tu-22M airplane for aerodynamic studies at real-flight Reynolds number;
- regional satellite communications center;
- development and manufacture of laser heterodyne-based measurement systems for science and national economy;
- development of the oscillating wing for propelling the ships;
- manufacture of flat solar collectors out of corrosion-resistant metals for industrial and domestic heating appliances;
- organizing manufacture of portable multifunction diagnostic medical complex;

- development, manufacture and commissioning of an environmental monitoring complex;
- woodworking plant based on advanced high-output processes.

③グロ－モフ飛行研究所
（モスクワ州ジュコフスキー）

I. Name of the Institute (Organization)

In Russian: Государственный научный центр Российской Федерации Летно-исследовательский институт имени М.М.Громова

In Russian abbreviation: ГНЦ ЛИИ им.М.М.Громова

In English: State Research Centre Of The Russian Federation Gromov Flight Research Institute

In English Abbreviation: SRC - FRI

II. Location

Official address: Zhukovsky-2, Moscow region, 140160, Russia

Mail address: Zhukovsky-2, Moscow region, 140160, Russia

Telephone number: (095) 556-5080, 556-56-07

Fax number: (095) 556-53-34

E-mail for representative: flysim-lii@mtu-net.ru

Website: http://www.lii.ru

Access (transportation, necessary time): Moscow international airport Sheremetjevo-2, two hours by car. The Institute is located 20 kilometers away from Moscow.

III. History

State Research Center - Gromov Flight Research Institute was founded in 1941 on the basis of the Central Aerohydrodynamic Institute to develop, research and construct the most advanced products of aviation engineering, remote control piloted aircraft and other items for different purposes.

The first head of FRI was legendary pilot and distinguished military leader, professor M.M.Gromov.

The FRI history covers:

- increase of combat aircraft effectiveness during the war;
- all the first jet-engined aircraft and later generation aircraft flight tests;
- investigations to provide significant systems, airborne equipment, aircraft and helicopter powerplant development;
- participation in the major space-research programs, which involved a large number of investigations including those on hypersonic aircraft and weightlessness problems, soft landing techniques and various recovery systems, simulators, etc.;

- for the last period time - research and development of the Buran AST systems, its flying prototype flights and crew training included.

Now Gromov Flight Research Institute. is a large research center dealing with development and testing of aviation equipment and cosmic equipment. It is experienced in organizing work in supersonic and hypersonic flying labs and simulators. It performs certification of aviation equipment, verifies its conformity to the norms of airworthiness, trains test pilots for aviation and astronautics and organizes ecological monitoring and solution of other tasks via aviation.

The international collaboration of FRI has long-standing traditions beginning with the legendary long-distance non-stop flights, mastering foreign-made combat aircraft during World War II, fire-fighting by test pilot Yuri Garnaev in 1960s. Highly beneficial are Franco-Russian and German-Russian cooperation in the aviation industry. The activities of specialists from FRI in scientific committees, working bodies of ICAO, ISO, the International Flight Safety Foundation (FSF) are also worth mentioning.

IV. Management

Kind of organization: State Scientific Center of the RF

Ownership: State Property of RF

V. Executives

Vyacheslav M.Bakaev - Head of FRI

Felix D.Zolotaryov - Manager

VI. Current major activities

The main directions of the institute's work are as follows:

- development of advanced flight test techniques;
- flight testing at the maximum flight modes;
- fundamental research using flying test bedsand flying models of problems of aerodynamics, thermodynamics, control systems, ergonomics and life-support systems;
- research work in the areas of flight reliability, maintainability and safety;
- development of powerplant, flight-navigation unit, other onboard avionics system and emergency escape system prototypes using flying test-beads;
- development of test data measurement, processing and transmission instruments;
- participation in the development of aircraft airworthiness requirements, integrated evaluation of aircraft compliance with the requirements;
- training of test pilots for airplanes, helicopters and aerospace planes;

• integrated flight testing and investigations of onboard and ground equipment and MLSs including all-weather operations;
• study of human factor influence on flight safety and development of means and methods of flight safety improvement;
• transportation, including heavy outsize cargo.
• creation of aircraft simulator for emergency rescue training (ТСАСП);
• creation of complexes, designed for air-borne earth monitoring (for environmental ecology, emergency prevention, mineral deposits exploration, boundary layer);
• development of small scale testing and regular control system and real-time diagnostics of aircraft system ("Regata");
• development and organization of measurement instruments for control and management of technological processes;
• organizing production of “Chirok” superlight all-purpose aerocraft-amphibian;
• packages development of training computer programmes and creation of unified computer class for flight and ground staff of various aircraft types.
• development a complex of aids based on satellite navigation systems (SNS) to provide support in approach to unequipped airfields.

The high-capacity flight-test complex having innovative airdrome ATC systems, trajectory cinetheodolite and telemetry measurement equipment based on the airdrome in the town of Zhukovsky, test ranges and stations in the localities near Moscow and southern zones practically provide any kind of tests and research.

The experimental and engineering production of FRI permits development and building of the unique flying testbeds, stand-modeling complexes, measurement, monitoring and recording equipment, instruments, systems for flight test and research data processing.

Important work is being carried out on the problems of building the winged space vehicles and systems (of precision space capsule landing, the problems of hypersonic aerodynamics and aerodynamic heating, etc.) together with European Space Agency (ESA).

Long-term collaboration with the aviation specialists and scientists from China develops successfully in the field of their aircraft and helicopter testing, increasing the efficiency of flight research through improving the methods, characteristics of measurement and recording devices, through developing specialized software to process the results and modelling, etc.

The unique airdrome location, availability of parking areas and access to rail and water ways, the large storehouses and latest airdrome landing systems have permitted a systematic international cargo and passenger transportation by the FRI airlines.

On a competitive basis with foreign investors and cofounders participation, problems of design and creation of the international airport with the required infrastructure by 2000-2005 are being considered.

VII. Number of employee

Number of employee: 7000

VIII. Major facilities

The FRI has a unique airdrome equipped with modern landing systems, airtraffic and flight experiment control systems. There are three runways, the biggest one being about 5.4 kilometers long. The FRI has over 70 flying test-beds, as well as airplanes and helicopters for transportation. The experimental production-engineering complex permits 10-15 flying test-beads to be equipped a year, and all types of research to be provided with instrumentation on its own design and manufacture.

The FRI has a large area of aircraft parking, hangar and other sites. Work is now being done to expand the existing sites due to increasing international freight operations and passenger services planned.

The Institute has a large fleet of flying laboratories permitting flight testing of any types of aviation and space apparatuses:

- a device for evaluating aerodynamic, strength, vibroacoustic and operational characteristics at all stages of a flight including critical conditions (stalling out, spin, etc.);
- facilities for finishing off software algorithms and equipment for on-board control complexes, solving the problems of navigation, directing, flight control, data displaying, communication and tracking;
- test benches for finishing off propulsion systems;
- facilities for testing lead systems of the flight critical conditions and means of emergency escape.

Flight testing is conducted using a ground control posts for flying experiments, and in case of a great airway - aircraft-command measuring posts.

IX. Commercial proposals

The FRI is highly integrated into scientific and technology cooperation on bilateral, multilateral and international basis.

The Institute provides a board array of experimental and expert services. The test and experiment facilities are available for the coordinated research within agreed programs and are also subject to separate agreements.

For more details, please refer to i.i. VII “Current major activities and VIII “Major facilities’ of the above document.

④ケルディシュ（ロケットエンジン）研究所
（モスクワ市内）

I. Name of the Institute (Organization)

In Russian: Исследовательский центр им. М.В.Келдыша

In Russian abbreviation: ИЦ им.Келдыша

In English: Keldysh Research Center

In English Abbreviation: KRC

II. Location

Official address: 8/10, Onezhskaya Str., 125438, Moscow, Russia

Mail address: 8/10, Onezhskaya Str., 125438, Moscow, Russia

Telephone number: (095) 456-4608; 456-8756

Fax number: (095) 456-8228

E-mail for representative: kerc@elnet.msk.ru

Access (transportation, necessary time): Moscow international airport Sheremetjevo-2, one hour by car.

III. History

Keldysh Research Center was set up by order No. 113 of the USSR Revolutionary War Council as of September 21, 1933, and decree No. 104 of the USSR Labor and Defense Council as of October 31, 1933, and its name then was RRI - Reactive Research Institute. It was established on the basis of Leningrad Gas Dynamics laboratory (LGDL) and Moscow group for studying reactive motion - MosGIRD. The Institute was headed by I.T. Klejmenov, military engineer, chief of LGDL, while S.P. Korolev, chief of MosGIRD, was appointed his deputy. At the first stage within the Institute the following structures were arranged: divisions engaged in the development of rocket gunpowder, gunpowder missiles, liquid-propellant rockets, launching facilities; divisions engaged in the development of liquid-propellant rocket engines (LPE), cruise and ballistic missiles, ramjet engines, gas dynamics and chemical laboratories, testing stations and workshops.

In the period of 1933-1940 the Institute completed the elaboration of high-explosive fragmentation shells designed for shooting at air, sea and ground targets, and they were put into service. Also in that period the work involving LPE using high-boiling fuel components (nitric acid-kerosene) was performed, which was supervised by V.P. Glushko. The development of oxygen-kerosene LPE was headed by M.K. Tikhonravov.

In the post-war period basic trends in the Institute activities involved R&D of rocket engines and power generating facilities for rocket and rocket-space complexes. Expansion of the R&D divisions gave rise to their isolation as independent experimental design offices (OKB). In the pre-war period the OKB headed by V.P. Glushko became an independent structure (now it is "Energomash" RPA), then the OKB headed by S.P. Korolev (now "Energiya" RSC) and OKB headed by A.M. Isaev (now KB of chemical machine building) were formed. The Institute affiliated branch, engaged in the development of gunpowder rocket engines, was transformed into the OKB developing solid-propellant rocket, A.D. Nadiradze became its chief.

In 1946 academician M.V. Keldysh was appointed the head of the Institute, who in 1949 became scientific supervisor of the Institute and occupied the position up to 1961. In the period of 1949-1958 the activities involving the development of powerful ballistic and long-range ramjets and anti-aircraft guided missiles were in full swing. Development of powerful LPE using cryogenic and stable components proved a success. The Institute staff made its contribution to the elaboration of the first in the world intercontinental missile and R-7 carrier rocket, which in its various modifications is used up to now.

Research conducted at the Institute for substantiating the LPE scheme with generator gas afterburning (closed-cycle) played a very significant role in the development of rocket engineering. Complex testing of model LPE with generator gas afterburning was conducted and confirmed serviceability of engines employing the scheme mentioned, feasibility of high pressure attainment in the combustion chamber and the resulting increase in the net specific thrust. The research laid the basis for extensive works involving closed-cycle LPE at all national KB developing engines.

A large affiliated branch of the Institute in Nizhnyaya Salda (now Research Institute of Machine Building) was arranged in 1958 to expand experimental research on LPE.

Efforts taken by the Keldysh Research Center resulted in revealing main mechanisms of processes that occur in the LPE units, and in developing modern methods of calculating thereof, including the LPE thermodynamic calculation method allowing to perform analysis of engines' power parameters. Issues relative to the application of different fuel components in LPEs have also been investigated.

The Keldysh Research Center has developed more than 50 types of low-thrust liquid-propellant rocket engines (LTLPE), that are component parts of the correction and orientation systems' actuators of almost all Russian spacecrafts, their thrust ranging from few grams to hundreds of kilograms. For such engines, there has been elaborated the philosophy of operating processes in pulsed and continuous modes providing: high-efficient carburation and fuel combustion in combustion chamber's small volume at small number of jet's elements, reliable combustion chamber wall cooling, and high dynamic parameters of engine’s reaching a rated mode.

IV. Management

Kind of organization: State Enterprise

Ownership: Russian Aviation and Space Agency

V. Executives

Dr. Anatoly S. Koroteev – Director, member of the Russian Academy of Sciences

Dr., Prof. Arnold M. Gubertov – Deputy Director

Dr. Yuri . Golovin – Deputy Director

Lorsana A. Besedina – Manager of the External Relations Department

VI. Current major activities

At present a variety of studies relating to elaboration of liquid-propellant rocket engines are conducted at Research Center.

- development of engines featuring large margins of serviceability constructed according to flowsheet approaches permitting minimization of the number of potentially hazardous aggregates;
- employment of emergency protection system and effective means of engine diagnosis;
- elaboration of propulsion facility redundancy principles, especially for piloted launching systems and launching systems for heavy classes of carrier rockets;
- reduction of the engine cost by using standard and cheap materials, technological processes, a simple and technologically efficient design of the engine;
- increase in the number of propulsion facility re-using, first up to 10-15 and then up to 50-100 times with utmost simplification of the interflight maintenance and reduction of operation costs;
- elaboration of cruise flowsheets of launching stages, assuring their multiple use (up to 200 times) and ruling out alienation of areas;
- solution of the problem of adverse effect produced by launching means on the Earth and near the Earth space ecology;
- studies relating to designing a promising kerosene-oxygen-hydrogen three-component two-mode engine (in cooperation with “Energomash” RPA);
- studies on the project of new generation oxygen-hydrogen engine for booster units and interorbital tugs (in cooperation with KB of chemical automatics);

- research on the project of a re-usable oxygen-kerosene LPE for booster units used for various purposes (in cooperation with “Energomash” RPA);
- study of fuel thermal conditions in the tanks;
- study of fuel tank supercharging and component drainage;
- research on fuel intake hydrodynamics under space flight conditions;
- elaboration of new types of fuel tank insulation.

On the basis of modern non-conventional technical and technological solutions, the following new generation LTLPEs are being developed:

- LTLPE based on long-storaged self-igniting fuel components for long-term orbital spacecrafts (over 10 years). One of the promising developments is a two-component LTLPE for the purpose of orientation, stabilization and correction of spacecrafts.

The engine consists of a chamber with a jet mixing head and two fuel-supply electric valves. Jet carburation technique provides a full fuel combustion in combustion chamber’s small volume and higher ecological parameters of the jet flame. LTLPEs are designed for highly maneuver small-sized spacecrafts of special purpose (brilliant pebbles). Reaction time of these engines is less than 5 ms, thrust-weight ratio is more than 1000. They have a high thrust impulse and small firing time (max 100 s). As a fuel for the said engines, both self-igniting and high-energy promising mixtures are being considered. Ultra-small thrust liquid-propellant rocket engines (less than 0.5 kg) are designed for spacecraft precise orientation and stabilization. The said engines operate on one-component fuel - hydrazine.

Research involving LPE engines using ecologically clean components has been conducted in the Keldysh Research Center since 1984 in cooperation with Russian Research Center “Applied Chemistry”. The research permitted designing and manufacture of an oxygen-methane LPE for finishing off and study of basic elements of combustion chamber in full-scale oxygen-methane engines, their thrust ranging from 100 to 2000 kN. The LPE has allowed finishing off.

VII. Number of Employee

Number of employee: 3500

VIII. Major facilities

Bench 4-5	Bench for investigation of liquid-propellant rocket engine	Working fluids: kerosene – oxygen and liquefied natural gas – oxygen. Thrust: $3 \cdot 10^4$ and 4000 N. Environment protection system in normal and emergency situations.	Investigation of liquid-propellant rocket engine on kerosene - oxygen and liquefied natural gas - oxygen (combustion

			chamber, launching procedures).
Bench 7	Bench for testing of low-thrust liquid-propellant rocket engine	Working fluids: unsymmetrical dimethyl hydrazine – nitrogen tetraxyde, hydrazine and others. Six work places, including ejectors and high-vacuum pumps. Thrust: up to 1000 N. Duration of testing: up to 2000 s (at thrust up to 100 N). Pressure in ejector plants: 1000 Pa. Pressure in vacuum plants: 10^{-2} Pa. Feeding pressure: up to 32 MPa.	Investigation, testing and trial of low-thrust liquid-propellant rocket engine.
Bench 12	Bench for investigation of liquid-propellant rocket engine (LPE) stability.	Working fluids: ethanol - air. Temperature: up to 800 °C. Pressure: up to 2 MPa. Flow rate: up to 20 kg per s. Modelling of liquid-propellant rocket engine combustion chambers of 2000 N-thrust. Launching components: triethylanine – AK-27. Feeding pressure: up to 20 MPa. Air flow rate: up to 2 kg per s. Ethanol flow rate: up to 4 kg per s. The bench is equipped with special diagnostic instruments for stability investigation.	Fire modelling of stability and efficiency of combustion process in liquid-propellant rocket engine combustion chambers, including full-scale ones.
St.-Peters-burg base	Bench set for LPE testing (two benches)	Working fluids: hydrogen – oxygen and liquefied natural gas – oxygen. Thrust: up to $3 \cdot 10^4$ N.	Investigation of LPE systems and units on components: hydrogen - oxygen and liquefied natural gas - oxygen.
SDS	Special differentiated bench	Working fluid: air. Braking pressure: 15 MPa. Flow rate: up to 15 kg per s. Braking temperature: up to 2000 K. Mach number: up to 6.5. Pressures drop: up to 3000. Single experiment error: by thrust coefficient: 0.08%; by side strength factor: 0.1%; by flow factor: 0.18 %.	Precision measurements of thrust coefficients and flow rate of nozzles and nozzles components of any unit aimed at the optimization of nozzle shaping.
TE	Set of benches for investigation of liquid hydrogen and other	Working fluids: liquid hydrogen, nitrogen. Vacuum system: Chamber volume: 60 м^3. Pressure: up to 10^4 Pa.	Investigation, testing and trial of spacecrafts engines and power plants models and full-scale elements, including:

	cryogenic components (fuel elements bench)	Cold simulator temperature: 78 K. Cryogenic system: Output: liquid hydrogen: 25 l per h; liquid helium: 10 l per h; cold production in cooler mode: 300 W Nitrogen system capacity: 6.5 t. Air flow rate: up to 5 kg per s (at pressure 30 MPa) Duration of testing: 10 days. Launching cost: 5 ... 10,000 dollars.	LPE feed systems; spacecrafts power plant long-storage systems; hydrogen- and oxygen-based electrochemical generators; heat exchanges and air-liquefiers for space engines.
SGU	Hot-plant bench	Alcohol and air heater. Pressure: up to 1.3 MPa. Temperature: up to 2200 K. Flow rate: up to 3 kg per s.	Development of benches designs for rocket engine testing simulating high-altitude conditions.

IX. Commercial proposals

Main directions of international cooperation are follows:

- research of processes in gas generators and LPE combusting chambers working on oxygen/kerosene fuel on the oxidizing gas generator chart with oxidizing gas dropping in combusting chamber;
- research of hardworking materials in oxidizing environment with high gas parameters (temperature and pressure);
- research of processes in gas generators and LPE combusting chambers working on oxygen-LNG (liquid nature gas) on the charts of oxidizing and reducing gas generator;
- research of processes in turbopumps working on liquid oxygen, hydrogen and methane;
- development and manufacturing of non-cooled nozzles from new carbon/carbon materials;
- research of high frequency and longitudinal stability;
- mathematical simulation and optimization of prospect LPEs with the experience of development and utilization LPEs;
- optimization of the contoured nozzles;
- optimization of design charts of the low-thrust LPEs

⑤化学自動化手段設計（液体水素エンジン）研究所
（ボロネジ州ボロネジ市）

I. Name of the Institute (Organization)

In Russian: Конструкторское бюро химической автоматики

In Russian abbreviation: КБХА

In English: Design Bureau for Chemical Automatics

In English Abbreviation: DBCA

II. Location

Official address: 22, Voroshilov St., Voronezh 394055, Russia

Mail address: 22, Voroshilov St., Voronezh 394055, Russia

Telephone number: (0732) 33-36-73, 33-47-11

Fax number: (095) 251-4449

E-mail for representative: cadbvor@online.ru

Access (transportation, necessary time): Moscow international airport Sheremetjevo-2, than train (8 hours) of aircraft (1 hour) traveling time to Voronezh.

III. History

The first liquid rocket engine was created in 1957. This was a two-chamber engine RD-0200 burning self-ignition fuel for the second stage of the anti-air missile by Designer General S.A.Lavochkin. The work was conducted together with the Isaev Experimental Design Bureau. In order to process the engine the construction of the testing bench was begun not far from Voronezh. This was the beginning of one of the largest test complexes for processing LPEs.

In 1958 collaboration between DB for Chemical Automatics and the Korolev Experimental Design Bureau began. In 1958-59 this co-operation resulted in the first engine – an oxygen kerosene liquid rocket engine RD-0105 with out a staged combustion cycle. It was the engine designed for the R-7 rocket's third stage which made it possible to increase the payload mass from 1400 to 4500 kg and to achieve the Earth escape speed.

The RD-0105 provided for the launch of the first spacecraft towards the Moon of January 1, 1959, the first «Earth-Moon» flight on September 12, 1959 and a flyby and imaging of the Moon's far side on October 4, 1959. Updating the RD-0105 engine has made it possible to create the RD-0109 engine with less mass and dimensions and an uprated reliability.

The «Vostok» space ship with Y.Gagarin onboard and all subsequent single-seater spaceships were equipped with the RD-0109 engine.

The powerful oxygen kerosene engines Rd-0107 and RD-0110 designed on the basis of the RD-0109, became the next DB for Chemical Automatics developments. These engines were used on the third stage of the «Voskhod» and «Soyuz» launch vehicle making possible the delivery of an up to 7000 kg payload to a near-Earth orbit. Up to end 1997 more than 2000 RD-0110 engines passed ground firing tests. The total engine operation time during the tests was about 300000 s. Success rate is 0.9984

The development of astronautics in the early 1960s required new, more comprehensive launch vehicles. DB for Chemical Automatics was one of the first to begin the development of engines of a fundamentally new design a staged combustion. In 1961 DB for Chemical Automatics launched the creation of RD-0202-RD-0207 series engines, two of which (RD-0202 and RD-0205) served as a prototype for future designs.

In 1962 DB for Chemical Automatics was involved in the development of a LPE for the heavy launch vehicle «Proton» able to deliver to orbit a payload with a mass of up to 20 tons. Thus powerful, highly efficient engines RD-0210 and RD-0211 for the second stage and RD-0212 for the third stage, burning high-temperature propellant were created. Due to high engineering efficiency the RD-0210, RD-0211 and RD-0212 engines have been providing for the launches of various satellites, automated station and the long-stay orbital station «Salyut» and «Mir» for more than 30 years. High economy, good performance and ease in operation have made these engines some of the best engines in the world in this class. More than 1000 ignitions of RD-0210 and RD-0211 were made during ground tests. About 900 ignitions were made during flight tests. On the end of 1997 the success rate was 0.99844. The number of RD-0212 (RD-0213) ignitions during ground tests was more than 600. Number of ignitions during flight tests – 218. On the end of 1997 the success rate was 0.99469.

In 1966-1971 DB for Chemical Automatics created the RD-0225 engine for the «Salyut» orbital station with a blow-out feed system, multiple ignition and a long time of staying in orbit with operation ability preservation. One of the engine’s particular characteristics is low pressure in the combustion chamber which has made it possible to work at low pressures in the fuel and oxidizer tanks. More than 13000 ignitions were made during ground tests. Eight ignitions – during flight tests. On April 8, 1982 the success rate was 0.993.

The RD-0215 engine development for a heavy launch vehicle which could burn nitrogen tetroxide/unsymmetrical dimethylhydrazine began in early 1960s. The engine is distinctive for the coaxial fixation of the turbo pump assembly and preburner mounted directly on the turbine’s casing and for the two manifolds for gas transfer from the turbine to the chamber’s head. In addition its oxidizer pump design foresees two impellers and two outlets and its fuel pump have two-stage construction. The experience gained with the RD-0215 was further used for the RD-0120 oxygen hydrogen engine development.

In the mild 1970s, using the accumulated experience the Design Bureau began to development engines (RD-0233-RD-0237) of a new generation series with a high pressure combustion chamber. Due attention was paid to reliability increase and design simplification. Thus a combustion chamber with an altitude nozzle was developed; a single multi-function automated assembly in the combustion chamber's fuel manifold was used instead of four units and the number of detachable connections was reduced. In additional new technological processes, including investment casting, combustion chamber's envelope calibration by the explosion energy, automated non-consumable electrode welding and other were widely used.

In 1967 DB for Chemical Automatics began to create liquid engines for the launch vehicles developed at the Experimental Design Bureau headed by the Designer General M.Yangel. The RD-0228 was the first engine burning nitrogen tetroxide/unsymmetrical dimethylhydrazine for the second stage of a launch vehicle. The engine consisted of a staged combustion, single chamber sustainer RD-0229 and a vernier RD-0230 four chamber engine without a staged combustion cycle. The new design solutions were intended to increase the reliability. In particular they considered the creation of a turbo pump with an impellerless nozzle and an axial turbine, a small preburner with a single-zone chamber and sprayers and heads of the combustion chamber in order to provide for the chamber's stable operation. The engine went into regular production in 1975.

In 1983-1989 the RD-0255 propulsion unit was developed and successfully passed the tests. The RD-0229 served as a prototype for the new engine which possessed an augmented thrust and was placed in the fuel tank. This significantly improved the dimension and mass characteristics of the launch vehicle's second stage.

In 1977 DB for Chemical Automatics began to develop the RD-0243 propulsion unit in cooperation with the Makeev Experimental Design Bureau. Thus unit consisted of the RD-0244 sustainer and the RD-0245 vernier burning nitrogen tetroxide/unsymmetrical dimethylhydrazine with a preburner oxidizer rich cycle. An original supply assembly gimbaled at an angle of ±45° was developed for feeding the oxidizing gas to the vernier's four chambers. Each engine has separate turbo pump and booster pump assemblies, preburners and automatics which are controlled by the solid-propellant gas generator gases. The RD-0243 is the best in energy and mass characteristics among the engines burning nitrogen tetroxide/unsymmetrical dimethylhydrazine.

The liquid hydrogen RD-0120 engine created in 1976-1990 is one of the latest Design Bureau developments. The engine is a sustainer of the second stage of the «Energiya» universal space system for launching the expandable orbiter «Buran» and other spacecraft with a mass of up to 100 tons. Four RD-0120 engines are used on the block «Ts». They are ignited together with the engines of the first stage for the launch vehicle lift-off and continue operation after the first stage separation. Their burn time is 490 and to 750 seconds. The creation of a powerful engine with high energy characteristics, burning cryogenic agents called for the solution of many scientific, design and engineering problems. It was necessary to build new production works with special equipment, develop new unique materials and set up a new experimental base. Solutions have been found for the engine testing procedures and for the multi-ignition. In addition new measurement tools have been developed and emergency protection systems and instrumentation for engineering checkout and diagnostics have been created. More than 800 firing tests with a total operation time exceeding 170000 seconds were carried out before July 1, 1997.

In 1990 a draft design was issued for the RD-0122 – a modification of the RD-0120. The RD-0122 has been developed for advanced, non-expendable launch vehicles with a larger thrust and high efficiency.

The development of LPEs for launch vehicles by the order of the USSR Defense ministry has been important at Design Bureau. These engines are modern in construction, have high energy properties, are technologically effective, need no maintenance and are highly reliable.

IV. Management

Kind of organization: State Enterprise

Responsibly Ministry: Russian Aviation and Space Agency

V. Executives

Dr. Vladimir S. Rachuk – General Director and General Designer

Yuriy A. Shipulin – First Deputy Director

Alexander V. Shostak – Director of Liquid Rocket Engines Research and Production Center

Sergei G. Valiukhov – Deputy General Designer for Conversion Programs

Zavizon G.I. – Chief of LPE Design Bureau

Rostislavin A.B. – Chief Engineer

Prigozhin V.I. – Director of Test Facilities

Feschenko A.I. – Director of Rocket Engines Plant

Viktor D. Gorokhov – Chief Designer of Space Propulsion Advanced Programs R&D

Georgy P. Sokolovsky – Chief of Information Department

VI. Current major activities

According to Federal Space Program DB for Chemical Automatics activity include:

- theoretical research in the field of liquid-fueled rocket engines;
- development of liquid-fueled rocket engines for first and second stages of

launch vehicles using both hypergolic and cryogenic propellant components;
- development of three-component liquid-fueled rocket engines;
- experimental work on liquid rocket engine designs, their components and subassemblies;
- expert evaluation of results from testing of units and subassemblies of LREs;
- development of new technologies for the production of liquid rocket engines.

The liquid rocket engine RD-0124 is being developed for the third stage of the modernized «Soyus-2» («Rus») launch vehicle. RD-0124 is a four-chamber liquid rocket engine with the oxidized rich cycle. It has preserved the dimension of its prototype (the RD-0110 engine) but possesses better parameters which provide for an increase in the injected payload by 900 kg. The engine burns liquid oxygen and kerosene.

Engine construction provides for rotation of combustion chambers at the maximum angle of ±3.5° in one plane around an axis which is perpendicular to the engine axis.

In 1996 engine ground firing tests began. It is planned that in 1998 the RD-0124 engine will be ready for flight tests.

Design Bureau for Chemical Automatics has fulfilled a wide range of design and research work, calculations and experiments on the creation of a tripropellant engine with a fuel rich cycle. The RD-0650 served as a baseline design.

The advantages of the engine with a staged combustion of the reducing preburner gas are high level of safety and combustion efficiency for the combustion chamber compared to the engines burning oxidizing gas in preburner. In addition the absence of oxidizing gas in the engine`s manifolds almost excludes inflammation.

The disadvantage is in the appearance of a solid phase in the combustion products. This reduces the gas burning efficiency and may cause contamination of the chamber head`s sprayer. Theoretical studies have shown that in certain conditions it is possible to avoid this situation. The tests conducted with various conditions of the kerosene non-complete combustion in oxygen with the hydrogen admixture have shown the correctness of the theoretical assumptions.

At the present time two modifications of the tripropellant preburner for conducting tests have been manufactured and tested according to a comparable testing program. They are being integrated onto one of the RD-0120 engines together with additional regulating and controlling systems. Several possibilities for the bench`s equipment have been developed for further tests.

A more complex version of the demonstration model plans installation of the feeding assemblies in the kerosene manifold together with an additional change in the hydrogen supply of the engine. It is possible to use this engine for the experimental launch vehicle.

The modernization of the RD-0120 engines (turbines, turbo pumps assembly, hydrogen

pump) will make it possible to optimize the tripropellant engine parameters.
This approach is distinctive in the use of assemblies already processed during the RD-0120 engine creation. This will make it possible to significantly decrease the time needed for manufacture and the number of tests. Consequently the cost of the new engine creation will be reduced.
In 1989 Design Bureau for Chemical Automatics began to develop small liquid propellant restartable sustainers intended for the oxygen hydrogen boosters and inter-orbital space tugs.
The RO95 engine is a staged combustion generatorless engine with separate fuel and oxidizer turbo pump assemblies. Both turbines burn hydrogen preheated in the cooling manifolds of the cylindrical combustion chamber and the nozzle.
The RO97 engine has a similar design. The hydrogen for both turbines is preheated in the cooling manifolds of the circular combustion chamber and the plate-type nozzle.
In order to increase pressure in the combustion chamber of an engine without a preburner it is necessary to increase the hydrogen temperature after the chamber's cooling lines. For the RO95 this is achieved mainly due to the chamber's wall ribbing from the side of the hot gas flow and the increase of the combustion chamber's cylindrical part length.
The use of an annual combustion chamber makes it possible to achieve a very high temperature for the cooling hydrogen. Consequently the dimension of the nozzle's cooled part can be decreased. It is also possible to use non-cooled carbon plastic nozzles in order to achieve the required degree of expansion. The use of a partially cooled plate-type nozzle will make it possible to avoid the application of special means during the ground tests to provide for the heating of the working agent in the chamber's jacket. This is because the escape of the combustion product flow in the nozzle's cooled part is eliminated.
The RO97A engine differs from the RO97 engine in dimensions. In addition it has a common turbo pump assembly instead of two separate turbo pumps.
The RD-0131 is a staged combustion hydrogen engine with a common turbo pump assembly and low-pressure oxidizer and fuel booster pumps fixed on the tanks of the booster. Uncooled carbon plastic is used for manufacturing part of the chamber's nozzle.
The RD-0132 engine is a modification of the RD-0131 engine with four combustion chambers.

Engine Burning Ecologically Pure Components

Design Bureau has developed and brought to mass production a series of highly reliable liquid propellant engines for launch vehicles of various class and destination, burning a toxic propellant (nitrogen tetroxide and unsymmetrical dimethylhydrazine).
With due account of the requirements for environmental protection Design Bureau has made calculations and performed tests in order to change to an ecologically clean propellant

combining oxygen and kerosene and oxygen and methane (or any other liquefied natural gas). Studies have confirmed the possibility of burning oxygen-kerosene in the RD-210, RD-0234, RD-0242, RD-0244, RD-0245 and RD-0256 engines and also oxygen-methane in the RD-0234 and RD-0256 engines. Independent investigation has confirmed the possibility of burning methane instead of hydrogen in the oxygen-hydrogen liquid engine RD-0120. This will significantly reduce the payload launch cost.

Studies have shown that no serious modernization of the engine`s assemblies will be required in order to change an engine to a new bipropellant combination. In most cases it is necessary to change the injectors of the preburner and the combustion chamber, modernize the axial loading off system for the turbo pump`s rotor and the pumps` seals and introduce ignition assemblies in the preburner and the chamber.

VII. Number of employee

Number of employee: 4000

VIII. Major facilities

DB for Chemical Automatics possesses facilities for ground processing of the created models and for necessary experimental studies. The facilities include a complex of up-to-date benches for the cold-flow and firing tests of liquid propellant rocket engines, their assemblies and units. Both real propellant agents (nitrogen tetroxide, unsymmetrical dimethylhydrazine, kerosene, liquid oxygen, fuel gaseous hydrogen) and model liquids and gases (water, naphthy, air, nitrogen and argon) are used for the tests.

The testing facilities are located 15 km from Voronezh. They cover about 112 hectares and include five firing benches and 21 benches for hydraulic, gas dynamic, structural, climatic and accelerated tests of liquid engines, assemblies and units.

The information computing complex provides for automated processing of the parameters measured during all firing tests.

In order to provide for bench operation the testing facilities are equipped with additional production facilities. The latter include warehouses for propellant components and materials, a boiler house, nitrogen and air compressor stations, power supply systems, bays for engine neutralization and overhaul, a chemistry lab, repair workshop and administrative building.

The DBCA`s cryogenic production facilities are adjacent to the testing facilities. These production lines produce liquid and gaseous oxygen, nitrogen for the testing benches.

Firing benches

Hydrodynamic test complex

Bench for autonomous processing of feed assemblies

The bench for feed system autonomous processing is intended for testing the main and booster pumps on order to check the working ability and resource. It also determines energy and cavitation parameters and the amplitude and phase characteristics for the modes very similar to the real operation conditions. The bench's equipment makes it possible to perform tests with de-aerated water and water saturated with gas.

Bench for hydrodynamic tests of the propellant mixing systems, automatics and the regulation systems

Benches for flow meter calibration

A complex of benches for the cold-flow autonomous tests

IX. Commercial proposals

DBCA is ready to participate in collaboration with foreign companies in the development of liquid rocket engines for launch vehicles in the following trends:

- development of oxygen-kerosene (methane) LREs with thrust power from 1 to 100 tf for foreign launch vehicles including design, manufacture of pilot pieces, experimental adjustment and also serial production;
- conducting of complex resource tests for foreign methane LREs, other components and separate aggregates at a test facilities of DBCA;
- development of elements and assemblies for foreign LREs on methane and other fuels;
- technical expertise of foreign LREs and their components;
- DBCA experts participation in analysis of abnormal occurrences with foreign LREs;
- development of proposals on improvement of foreign LREs design and production technology.