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Chapter 3

THE FOUNDING OF THE JET PROPULSION RESEARCH INSTITUTE AND THE MAIN FIELDS OF ITS ACTIVITY*

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Now that astronautics has become an important sphere of man's activity, a large industry comparable in scope with aircraft production has firmly established itself in our everyday life (television, weather forecasting, etc.), and one is tempted to turn to its sources and retrace its history. This year gives us a good opportunity to indulge in such retrospections as it is the 50th anniversary of the founding of the Jet Propulsion Research Institute, an organization specially concerned with jet technology. This institute was the first of its kind, not only in the Soviet Union but in the whole world.

It would not be correct to presume that the institute started from scratch. Long before its emergence, rocket technology enthusiasts in the Soviet Union joined their efforts in the Gas Dynamics Laboratory (GDL) in Leningrad and in the Group for the Study of Jet Propulsion (GIRD) in Moscow.

For in those times, these two organizations rated among the larger ones. The Leningrad GDL mainly specialized in artillery. It was headed first by Tikhonmirov, then by Petropavlovsky. The work they had started led to the emergence of widely known rocket artillery that played an extremely important role during World War II. But rocket artillery was not the only field of the GDL's activity. Suffice it to say that one of its members was Glushko, who devoted himself to the development of liquid-propellant rocket engines. Space orientation, so to speak, was also the trend in a group of Moscow enthusiasts incorporated in the GIRD. Here, the master minds were Tsander and Korolev who investigated problems involving today's astronautics. Since these two organizations worked simultaneously on closely related problems in two different cities, and their leaders, as well as the rank-and-file members, felt the need for joining their not numerous forces in a single organization, the idea naturally arose to create a single jet propulsion research institute. The leading role in the formation of the Institute belongs to the Leningraders. In 1932, Rynin, Perelman, and Petropavlovsky wrote a letter on behalf of the Leningrad scientists in which they proposed to join their efforts. In 1933 similar ideas were put

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forward by both the Leningrad GDL and Moscow GIRD members, which shows that both organizations strove for a merger.

In order to give investigations in rocketry the necessary scope and raise them, in terms of planning and execution, to the level of state importance, a decision was taken to conduct them within the framework of the People's Commissariat of Heavy Industry, which included at that time both aircraft and artillery plants and institutes. This provided the necessary conditions for establishing business cooperation with relevant bodies and enabled the new organization to rely on the entire might of the aircraft and artillery industries, thus opening much broader possibilities for fruitful activities. In October 1933 the Council of Labor and Defense issued a decree that set up the Jet Propulsion Research Institute (RNII), thus starting the history of this remarkable organization.

The plan of work drawn up right after the formation of the RNII devoted much attention to the development of rocket artillery. It was an important task, and owing to its successful fulfillment, the Soviet Union entered World War II armed with rocket projectiles that could be fired from aircraft and highly mobile (truck-mounted) launchers. The history of the development of rocket artillery armament could well be the subject of a separate report, and goes beyond the scope of this communication, which is confined to the institute's activity in the field of space technology.

As regards the investigations which paved the way for space flight, the main problem addressed was the development of a reliable liquid-propellant rocket engine. Understandably, there was no point in speaking about rockets until such an engine was created. Given priority attention, large-scale work on this problem got under way. Already in 1933 Glushko's engine ORM-52 was subjected to an official trial. The term "official" deserves special explanation. As is known, trials may be of different types. Unlike a routine trial which is conducted by the engine designer himself with a view to obtaining the data he needs, an official trial is aimed at testing an engine against the technical requirements established by an outside organization. During official trials, all formal and technical rules must be strictly observed and all those who have had experience with presenting some products for official trials know only too well the difference between such trials and conventional bench tests arranged for the designer's own needs.

The year 1936 witnessed the official trial of the ORM-65 engine, which was installed in Korolev's rocket 212. It had been also used originally with the rocket glider 318. To make a long story short, it was in small-scale batch production. Mention should also be made of the well-known BI-1 fighter plane flown in 1942. It was powered by a liquid-propellant rocket engine also developed in the Jet Propulsion Research Institute. In 1944 a test was applied to yet another engine designed by Isayev, who was at that time working at the Institute. As we shall see, all the main engines developed in those years for rocket-powered vehicles were directly connected with the activity of the RNII.

A more detailed analysis of the investigations connected with the development of engines reveals the remarkable scope and depth of the institute's scientific en-

deavor. Of special significance was the intensive researches carried out simultaneously in the possibilities of low-boiling and high-boiling oxidants. The investigations conducted in the first field were aimed at developing alcohol-oxygen engines (with a prospect of changing over to kerosene-oxygen propellants), whereas efforts made in the second field concentrated on the development of engines using kerosene and nitric acid. In both fields, intensive experimental and theoretical work was under way on such problems as the atomization of fuel components by injectors, formation of combustible mixture in engine chambers, as well as the problem of engine cooling, particularly with propellant components (the possibility of such cooling was seriously called in question in those days). Efforts were also made to improve the engine starting procedure (including the procedure of multiple starts), to develop methods for increasing the efflux velocity or, using the terminology of that period, the engine specific impulse, and to develop gas generators without which the modern rocket engine would be simply inconceivable. Among the subjects of scientific investigation were also a few "exotic" themes which died a natural death, such as the use of ceramic lining for protection of the combustion chamber inner surfaces from high temperatures.

As we see, the subjects that were in the focus of the researchers' attention in that period differ but little from those under investigation at present. The only new problem to emerge since that time is that of stability of the engine working process. In the early period of the institute's activity the researchers did not go into the intricacies of stable operation of liquid-propellant rocket engines, and did not study the phenomena of high-frequency oscillations. As regards all other problems, they are as topical today as they were in those years. This circumstance testifies to the fundamental nature of the investigations carried out by the Jet Propulsion Research Institute.

Besides the study of liquid-propellant rocket engines, the RNII was also engaged in the investigation of air-breathing turbojet engines. The aircraft industry of those years was practically unfamiliar with this type engine which represented the future of jet-propelled aviation. It is to the institute's credit that the problems related to this engine figured prominently in its plans. The institute mainly engaged in developing the ramjet variant, which is still being used. The researchers concentrated on the process of combustion in ramjet engines and strove to improve their efficiency. The work was limited to subsonic engines. Theoretical studies conducted at the institute included investigations into the problems of turbojet engines, as well as into the principles of motorjet engines, now practically forgotten. Later the Institute also started work on designs of turbojet engines. All this convincingly shows that the RNII stood at the very source of the present-day problems in the theory and practice of aircraft engine construction.

As regards rocket technology proper, the RNII was actively engaged in the investigation into the possibilities of rockets which could be given today the name of ballistic missiles. The existence of such a trend was only too natural, though it was confined to the development of rockets for research purposes, mainly for meteorological studies. The reason lies in the fact that the thrust developed by engines in those years was not yet sufficient to lift heavy payloads, and the rockets

therefore could hardly be used for combat purposes. Despite this fact, the development work on such rockets continued, and efforts were made to provide them with gyroscopic controls. On the whole, however, this work was of secondary importance.

By contrast with ballistic rockets, winged missiles enjoyed far greater attention. This was accounted for by fact that the weight of such missiles could be several times greater than the thrust of the rocket engine. Among such missiles were models 216, 212, 312, and 301 developed under Korolev's guidance. At that time Korolev was in charge of the team developing surface-to-surface (model 212) and air-to-air (model 301) winged missiles both of which were brought to the flight test stage. As distinct from earlier missiles, model 301 was not only equipped with gyroscopic autostabilizers, but also with radio guidance means, i.e., it already possessed all the basic elements of modern missiles of this class.

The development of the above missiles called for considerable effort to improve the automatic control system. The researchers developed gyroscopic instruments of the autopilot type suitable for operation under specific missile conditions. Understandably, they were made at the technological level of the 1930s and do not compare with modern gyroscopic automatic control instruments, if only because they were pneumatic, not electrical. In view of the difference between the technological levels, the automatic control of the 1930s rockets cannot be identified with those of modern ballistic rockets, yet it is highly significant that the former included all the key elements of automatic navigation systems. They comprised servo units, appropriate control programs, two gyroscopes and flight data automatic recorder system. As regards the theory of flight of winged missiles with automatic controls, the investigations in this field were far more advanced than the similar investigations in aviation. The theory of autopilot-controlled flight in aviation was practically at a standstill since the problems connected with such a flight were not very topical. Aircraft were mainly controlled by hand and their autopilots, unlike those of rockets, could be easily adjusted in flight. As regards rockets, their autostabilizers had to be adjusted on the ground without preliminary flight tests; therefore, great importance was attached to the theory of automatically controlled missile flight. In this field Korolev's group obtained essential results.

Alongside the development of flight machine designs and theoretical investigations directly linked with such development, the Jet Propulsion Research Institute carried out extensive research in supersonic wind tunnels. Its should be noted that the RNII was the only organization in the Soviet Union which had supersonic wind tunnels. They were employed for detailed investigation of jet nozzles with a view to optimizing their shape for subsequent use in jet engines. Significantly, already at that time, the researchers understood that it was desirable in some cases to heat the gas in the tunnel; therefore heated-air wind tunnels were developed. We shall not discuss here in detail the investigations carried out by the institute in the field of gas dynamics, since they were mainly aimed at obtaining the characteristics of projectiles, but not engines. These investigations were indeed very helpful in developing good rocket projectiles.

Besides design work, RNII members participated in research activity connected with rocket technology. For instance, the institute's scientific workers took

part in the conference on stratosphere studies organized by the Academy of Sciences of the Soviet Union in 1934. This conference was mainly devoted to high-altitude balloons, but its agenda also included several reports on investigations of the stratosphere with the help of rockets. These reports were made by Korolev, Pobedonostsev and Tikhonravov. Another all-Union conference held a year later was devoted to the use of rocket vehicles in the investigation of the stratosphere. The reports were again made by Korolev, Glushko, Tikhonravov and Pobedonostsev. The RNII representatives thus participated in various scientific conferences at the highest level. The scientific workers of the institute also issued monographs which later became text books, and served as guides to rocketry for many enthusiasts who decided to follow their calling in life. Of such books I shall mention *Rocket Flight in Stratosphere* by Korolev, *Rockets, Their Design and Application* by Langemak and Glushko, and *Introduction to Astronautics* by Shternfeld. All of the authors were RNII workers.

In the period from 1936 until 1940, the scientific workers of the institute issued nine collections of articles on rocket technology in addition to RNII Transactions. This is convincing evidence that the RNII engaged not only in extensive design work and applied research but also carried out fundamental investigations. Its workers participated in scientific conferences sponsored by the U.S.S.R. Academy of Sciences, published books, issued collections of scientific articles summing up the results of their investigations, etc.

The brief survey of the RNII activity that I have made testifies to the broad range of research and scientific insight of its leaders: In point of fact, fifty years ago the institute concentrated on just those fields of rocketry which are in the focus of the scientists' attention today (rocket engines, autostabilizers, gas dynamics, rocket flight theory, etc).

Toward the end of World War II there appeared two tendencies that acted in opposite directions. On the one hand, the institute began to expand owing to the influx of fresh forces; on the other hand, it started dividing into independent research organizations.

Groups of scientists who had begun to study the problems of jet propulsion in other centers joined the RNII. For instance, such scientists as Sedov, Petrov, Abramovich, Pilugin and others transferred to the RNII from the Central Aerohydrodynamics Institute (TsAGI). Another body that joined the institute was Bolkhovitinov's aircraft design bureau, which had developed the rocket interceptor plane BI-1. A number of combustion theory specialists, including Gukhman and Knorre, came from the Leningrad Central Boiler-Turbine Institute. In 1946 the institute was joined by Keldysh. Hence, the RNII drew all those who were concerned with rocket technology. However, in view of the rapid expansion and specialization of its activities, the institute, which was the sole and universal organization in the highly sophisticated and extremely important field of jet propulsion started breaking up into specialized institutions - one for projectiles, another for liquid-propellant engines, a third one for control problems, a fourth one for ground facilities, etc. At different times the RNII gave birth to two independent design bureaus - one headed by Isayev which later played an important role in the development of Soviet

space technology, and the other one headed by Lulka that was concerned with aviation problems. It is appropriate here to mention that the first Soviet turbojet was developed in Lulka's bureau. Another independent design organization born within the institute was Bondaryuk's bureau concerned with the ramjet design.

The history of the Jet Propulsion Research Institute in its initial organizational framework lasted but little more than a decade. The institute was set up in 1933, and ceased to exist in its original form in 1945-1946. Its scope began to narrow and it gradually lost its significance as a universal research center representing such diverse fields as artillery, rocket design, liquid-propellant rocket engines, automatic control systems, gas dynamics. This center had played a unique role in the development of Soviet aerospace investigations. Its leaders, such as Kleimenov, Langemak, and Korolev clearly understood that all the problems tackled by the Jet Propulsion Research Institute were important, and that it was impossible to develop, for instance, rocket engines or automatic controls without paying due attention to other fields. As soon as one or another trend gained sufficient strength and was able to sail on its own, no one attempted to prevent its separation from the institute - on the contrary, such an event was always welcome.

Modern space industry is an extremely complex field linked with practically all branches of science and technology. Looking back now at the history of the Jet Propulsion Research Institute, one can plainly see that all the trends of modern rocketry have their roots in that glorious decade. The history of the RNII, conceived and set up as the center of Soviet rocket studies in the early 1930s, came to an end with the termination of World War II. It was indeed a short but glorious history.