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Chapter 5

SCIENTIFIC AND TECHNOLOGICAL PREREQUISITES FOR THE FIRST MANNED SPACECRAFT*

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When today one looks back at the path covered by cosmonautics, particularly in the first decade, beginning with the creation and launching of the first Sputnik, the "explosive" character of the initial period of its development seems surprising.

Indeed, during that period the Soviet Union launched three Sputniks, three Luniks, some Sputnik prototypes of piloted spacecraft, and, finally, the communication Sputnik "Moniya," and probes sent toward Mars and Venus, and so on.

Only three-and-a-half years had passed since the first launching of the Sputnik (which was actually only a small-size sphere with the simplest equipment aboard) to the flight of Yuri Gagarin into space; this fact, which now seems nearly fantastic, may serve as a vivid example, illustrating the "explosive" character of space technology development.

A natural question crops up: what was the reason for that "explosion"? This question is more easily answered when it is paraphrased thusly: Was it really possible to create spacecraft in the 1930s or 1940s? I believe that the creation of a Sputnik, analogous in design to the first one, was a feasible task, even in the 1930s. However, in the 1930s there already existed a great technical potential, which could, in principle, make possible creation of space vehicles (At our disposal were light-weight materials, the science of air-tight sealing of volumes, electric current sources, electronic equipment, particularly radio-apparatus, experience with the existence of human beings in closed space, for instance in submarines, and even, though not as yet fully developed, but an actual theory of spaceflight). However, it was impossible to realize that potential, because there was no carrier rocket to put a spaceship into orbit.

In fact, this was the reason that led to the "explosion." Creation of a rocket-carrier nearly immediately (as to historical measurements) liberated possibilities which were inherent in the preceding technology development.

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A number of additional circumstances should be mentioned. First of all, the first spacecraft were relatively simple in design. Even if we compare "Vostok" with "Mir," "Salyut" or "Soyuz," then the great difference in the complexity and efficiency of these vehicles becomes evident.

On top of this, we must take into account that the teams which took up the development of the new space technology were young, courageous, without any technical prejudice, a fact which allowed them to solve the tasks never taken up by "serious" people. And certainly one should not forget that at the head of these investigators, young (not always by age, but always in spirit) scientists and engineers there stood a wonderful man, Sergey Pavlovich Korolev.

Thus, such quick and sensational development of space technology during the first years was principally determined by three main factors:

1. Great scientific and engineering reserve obtained in other fields of technology;
2. Relative simplicity of the tasks solved within the first years;
3. Courage and absence of any fear of the new by designers.

However, it would have been a grave mistake to believe that the old reserve obtained from other fields of engineering was enough to create a conceptually new field of technology, namely spaceflight technology. It had to be enriched by new, specific, and, as a rule, highly urgent scientific explorations. The work in the line of certain tasks, already possessing specific space flight features, began long ago. Although small teams worked within that field, they worked intensively, and their efforts were not in vain. I now recall the years of 1936-1937. During that remote period of time, S. P. Korolev's team was working on a project of a boost-glide aircraft with a liquid-propellant rocket engine. The aircraft was intended for breaking flight altitude and speed records. It is of interest that the project provided for full-pressure suits and a pressurized two-seat cabin, (i.e. the elements which appeared later aboard spaceships). The project was not carried out; it did not even reach the modeling stage. Surely there were no significant scientific results that could possibly be obtained. I simply want to demonstrate by this example that even as far back as the 1930s, Korolev was seriously considering the problem of manned-flight beyond man's natural living environment, at such high altitudes that an artificial medium was required.

It is not surprising then, that long before the space era, late in the 1940s and early in the 1950s, Korolev, in cooperation with medical men and biologists, put up a number of experiments on stratospheric rockets with animals and scientific equipment aboard, which gave us our first knowledge about space. His organization accumulated scientific and experimental data and worked upon the rocket design for vertical manned-flight at 100-200 km. These projects were analyzed in detail and, to the credit of Korolev, it should be mentioned that he considered it unnecessary to fulfill these projects, since it was obviously a blind alley, along which, by the way, the Americans went. Korolev had the courage to switch immediately to the development of a project providing orbital flights. By these examples I want to show that, long before the creation of the first Sputnik, Korolev's entourage already thought of manned flight in space. I speak about the "entourage" on purpose, because there exists an incorrect notion that all the new ideas belonged to Korolev alone. Never could a single man invent everything that was achieved by such rocket-space engineering. Korolev was "the center" of idea concentration, the leader, and at his "headquarters" other very often outstanding scientists were working and made invaluable contributions to the cosmonautics development.

Thus, alongside the great scientific potential that was accumulated, and the field which was opened by the creation of a rocket-carrier, there existed a parallel field, namely the development of specific problems, the solving of which could be of use to future manned flights.

About 1953-1954, that is before the first Sputnik launch, very intensive and serious explorations began along the lines of scientific problem solving required for the creation of automatic Sputniks and manned spaceships. In enumerating these tasks and explaining their significance, I will try to single out those which were connected with manned flight, since the topic of my paper is the creation of the first "Vostok" and the first flights of our cosmonauts.

A great number of serious questions (not contained in the technical potential acquired before the spaceflights in the other fields of engineering) for which answers could not be obtained from the vertical rocket launchings, proved very valuable for science and were the subject of independent studies. I will speak about these problems, without claiming to give a full account of the subject, fully and without strict chronological order.

First of all, it was necessary to study the physics of space. Our view, which existed before the space era, that beyond the Earth's atmosphere was complete emptiness, appeared to be profoundly wrong. But what was actually beyond the atmosphere? This was impossible to comprehend with the measurements made in experimental launchings; a more serious analysis of the results obtained was necessary to create a reasonable theory, which could explain not only these measurements, but also a number of attendant circumstances.

In these scientific studies, an invaluable role was played by Academician S. P. Keldysh, whom we justly place along side S. P. Korolev. He coordinated and led scientific research which made spaceflight possible in general, and a manned flight in space in particular. That research resulted in finding areas of intense radiation surrounding the Earth, whose existence was never suspected before the space flights. It appeared that radiation within these areas was so intense as to be dangerous for man's life. It was thus necessary to study and comprehend this new obstacle. As a result of these investigations, it appeared that only a very narrow altitude corridor was safe for long flights. Below 200 km this corridor was bordered by a thick atmosphere which greatly decelerates a spacecraft, and at about 400-500 km, radiation begins to increase. A short-time crossing of the radiation belts, as in the case of the American Moon flight, is not dangerous for the cosmonauts. Thus, it can be seen that before undertaking a spaceflight, serious scientific analysis of the space situation was necessary; here it was necessary to find the altitude range admissible for manned flight on the near-Earth orbit. Simultaneously, radiological radiation danger was examined as to Sun flares, a sudden great radiation increase. Thus, radiation measuring service appeared to be necessary to carry out spaceflights, and certainly it could not exist before the Space Era.

Let us consider another question which seems to be simple: That is, what are the trajectories for flight, and how does one fly on them? By this, I mean the ballistic provision of the spaceflights.

Generally speaking, before the 1950s, spaceflight theorists in our country (as well as abroad) had already certain works on the application of laws of celestial mechanics to space vehicles. Those are the works by V. Homann (Germany), F. Tsander and A. Shternfeld (U.S.S.R.), and others. But these scientists were mainly engaged in interplanetary flight problems, and Gagarin had to fly around the Earth. And this happened to be quite a different problem.

That problem was to be solved by a number of specialists, including a team of young scientists headed by Academician Keldysh at the institute now named after him. They began a thorough and systematic study of Sputnik trajectories. It appeared that classical celestial mechanics methods, known for many centuries, were of no use for the near-Earth trajectory calculations, because the employment of these methods for estimation of the Solar System planets' movement did not take into account a number of factors, which were justly considered as unessential and yet were vital for calculating near-Earth orbits. Thus, for example, nobody was engaged in the problems of mass movement deceleration in interplanetary space or its impact with some particles; even if it existed, it was considered to be negligible. At the same time, the Sputniks were decelerated in the atmosphere, and in the long run fell down to the Earth. That is why it was necessary to study the problem of deceleration and its regularities. In calculating trajectories, it was necessary also to take into account the unsphericity of the Earth. The Earth in fact is not a sphere, but a more complicated body. It appeared that fact greatly influenced the artificial Earth-satellite movement. Certainly the Moon also moves around the Earth, but, being far away, these factors are negligible for her. However, for spacecraft moving around Earth at the altitude of 300 km, these factors are of great importance.

Thus, without these works it would have been impossible to determine the time of Sputnik's life and to calculate the trajectory of its flight above the Earth's surface (that is to determine the track of its next circuit). And without this data, the Sputnik's flight and its control, the selection of landing site, the distribution of communication sessions—all that has now become day-to-day work—would have been impossible.

But speaking about Gagarin's flight, the problem of ballistics was even more acute. The thing is that the ship Vostok, because of its deficiency in carrier lifting power, was designed with one somewhat risky exception from the general rule. Usually Korolev doubled all of the systems. In Vostok, everything was doubled except the retrorocket engine. Had it failed, it would have been impossible to leave orbit. Later, the stand-by systems appeared, but for the first flight there was a problem of substitution for that missing engine in case the main one failed. The solution found was purely ballistic. Because by that time the science of Sputnik movement within near-Earth space had been relatively well developed, thus a ballistic trajectory was successfully chosen, so the prearranged Sputnik's life-time was more than two or three days, but less than eight or ten days, (i.e., even if the engine failed to start, which was improbable, the spacecraft would have, in any case, descended to the Earth because of the natural deceleration in the atmosphere). And the air and food supply aboard the ship was for 10 days. Such ballistic provision of that flight became possible as the result of the near-orbit research work carried out at the scientific centers of our country.

The next problem was the problem of heat. The space-vehicle cabin had to be provided with normal thermal conditions, while the vehicle itself was either subjected to the torrid effect of the Sun's rays or was immersed in cosmic coldness when entering the Earth's shadow. In solving that task, it was necessary to take into account the fact that the traditional method of heat convection, which existed in all technical devices on Earth, was absent in space. Of primary importance in space is emission, a phenomenon of subjective significance for the machinery and apparatus of the Earth. Thus, a number of scientific problems sprang up, which needed solutions to determine light absorption and light reflection coefficients, etc.; without solving these problems, it was impossible to provide reasonable thermal conditions inside the space vehicle.

A very serious problem also concerned the spacecraft thermal protection on entering the atmosphere. The reentry speed into the atmosphere is about 8 km per second. At that time the metal melts, and burns up. Thus, it was necessary to protect the cosmonaut from that terrible fire. Therefore, a new heat-protective coating had to be developed to build up a complex theory of air flow around a body at cosmic speeds. This theory considered complex physical and chemical transformations which take place during the flow. There was no such theory in the traditional aerogasdynamics. Besides, it was necessary to provide certain thermal conditions inside the cosmonaut's cabin, to isolate it from external heat during spacecraft reentry of the atmosphere and in its landing deceleration.

The great and independent problem was the task of creating spacecraft movement control systems. This required, first of all, working out the theory of control, and then developing corresponding control devices. Originality of the scientific problem of attitude and maneuver control was due to the fact that, as distinct from all existing transportation facilities (e.g. ground, above-water, underwater, air, and even rocket-carriers), the movement around the spacecraft mass-center (turns) did not influence the movement of its mass center (i.e., did not alter the flight trajectory). It led to the development of a wide and peculiar section of control theory; that is control in outer space. Certainly, in 1961, that part of control theory was as yet in the making; but the flight of Vostok, and of a number of other spacecraft, became possible only because the main results of this new scientific trend had already been found.

Some additional tasks sprang up for Vostok connected with manual control. Here the problems of mechanics and control theory joined the problems of engineering psychology. In the whole volume, these complex problems became evident later when the problems of manual control became more complicated, but in the Vostok they were also urgent enough.

In short, we see that the development of cosmonautics demanded during those early years the prompt solution of a great number of very serious problems which were in addition to the scientific and technical reserve which existed at that time. Even such a problem as weightlessness was not only of medical and biological significance, but also of importance for apparatus, because there was no thermal convection in weightlessness; hence for example, the cooling of radio components in space differed from those on Earth.

The vacuum problem was of interest to scientists not only from the point of view of the necessity of pressurization, since such problems had been solved in the case of terrestrial devices before. It happened that the space vacuum so much exceeded the terrestrial one that the materials exhibited somewhat different properties. The problem of friction of moving parts in the space vacuum appeared to be rather serious and surprising. For example, the gear wheels which worked on Earth practically for unlimited periods of time, did not work in the space vacuum for long and were pulverized. Self-welding of moving parts or of separate metal pieces could take place. But this problem was also solved.

A systematic approach was characteristic of Korolev's and Keldysh's guidance style. They would not solve a certain important problem in one step, but overviewing all the problems, would solve them stage by stage, to the first approach, in its simplest form, but quite sufficiently for that flight, and then further on and more profoundly.

Such a systematic approach embraced all of the problems; and, yet at the same time, they understood that it was impossible to solve all problems to the very end within two or three years; thus they set reasonable tasks within reasonable terms, and set aside more serious theoretical problems to be solved later, which contributed to the vigorous growth of space technology during the first five or ten years of its existence.

Thus it is evident that alongside the utilization of the scientific margin reserves, a serious role was played by the total combination of scientific research, carried out at various scientific centers, solving the problems specific for flight into outer space.

Now, 25 years after the first piloted flight, it can be seen that the totality of problems solved during the first years, was chosen correctly. The following years made it possible to deepen the knowledge in these fields of science, but no new practical problems appeared. All the main problems were embraced during the first five years of the Space Era development.

Today our knowledge, certainly, is far greater than that which made the flight of Yuri Gagarin possible. However, in surveying all that occurred 25 years ago, we are amazed at the purposefulness and completeness of the research which made possible the flight of the spaceship Vostok, piloted by Yuri Gagarin.