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Chapter 10

THE DEVELOPMENT OF SPACE FLIGHT THEORY BY SOVIET SCIENTISTS*

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This brief report cannot embrace all scientific ideas, theoretical researches, and preliminary designs of the late 1920s and early 1930s which were devoted to substantiating the possibility of flying into space with the use of jets. Limiting myself to the works of the most prominent scholars of that time—K. Tsiolkovsky, F. Tsander, and Y. Kondratyuk—I will try to evaluate the level of their foresight through their contribution to the development of space machinery, and the fundamentals of space theory in its initial stage. It is inevitable that some of their ideas to be utilized in future will not be covered in this paper.

The turn of the 19th and 20th centuries saw the appearance of the gigantic scientific phenomenon of K. Tsiolkovsky. He was the first to work out the main theorems of modern space machinery, to depict the spacecraft, and, to mark good prospects for liquid propellants. He compared various types of propellants, emphasizing that the combinations of hydrogen and oxygen, and of fluid hydrocarbon and oxygen, had a great future. It is common knowledge that these types of propellants are widely used in modern spacecraft. Tsiolkovsky paid great attention to the question of the respective parts of propellant consumption to overcome air resistance and the Earth's and Sun's gravity. Tsiolkovsky's works contain a lot of interesting ideas of the peculiarities, as we nowadays put it, of certain systems of the spacecraft. In particular, he noted a method of turning the rocket by changing the direction of the propulsion jet from the engine nozzle by means of jet tabs. He also noted the possibility of using big flywheels to turn a space apparatus, suggested using under-pressure an oxygen atmosphere, and of adjusting temperature inside the spaceship by changing the respective volumes of the absorbed and reflected radiant energy of the Sun. He also designed the spacesuit and other things.

It is obvious from Tsiolkovsky's works that he realized the necessity of automatic devices to control space flight. He said, in particular, that is was impossible to direct the engine thrust line exactly through the rocket's center of mass, and that necessary corrections had to be done automatically. For a straight flight, he sug-

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gested using an optical device automatically reacting to any deviations from the direction to the Sun, or a . . . "case with two circles quickly rotating in different planes. The case is suspended so that its position, or rather its direction . . ." [1, pp.28,29] does not depend on the rocket's angular motion. As a matter of fact, he suggested using a system of two unadjustable gyros for a short-term "remembering" a certain direction, as is done nowadays for maneuvering in space.

As far as reentry goes, Tsiolkovsky suggested using the braking action of the atmosphere, and switching on the jet engine only to give the spaceship a slight momentum, pushing it from an Earth satellite trajectory to a reentry one. It is presupposed that the reentering apparatus will glide, changing the aerodynamic lift through adjusting the angle of attack. The advantages of water landing were noted.

A great deal of what was mentioned above was utilized in the Soviet and U.S. space programs, and we surely can speak of the great significance of Tsiolkovsky's works, not only as fundamental works of a general character, but also as a source of a number of concrete technical ideas, the realization of which became possible and expedient in the first decades of the Space Era. It should be noted that Tsiolkovsky, speaking of the fact that creating or building has always followed scientific calculations, with the latter being preceded by a fantasy, considered his works to be the middle phase of the creative triad. His letter to the editor of the magazine *Scientific Revue* (1903) read as follows: "hundreds of years will probably pass before my ideas are fulfilled." [1, p.131]. Maybe it was this consideration which kept Tsiolkovsky from a more thorough development of technical details of future space programs. But he paid much attention to the goals of space exploration, thinking that mankind should start with the Solar System, and after that move outside its limits.

F. Tsander and Yu. Kondratyuk belong to another generation of space-machinery pioneers. The problems of technical realization of space programs occupied a greater part in their works than in those of Tsiolkovsky. Tsander dreamed of the future of cosmonautics as a natural continuation of aviation. He agitated for the used of aviation principles for the initial [takeoff in the atmosphere] and final [reentry in the atmosphere] stages of spaceflights. In his opinion, "it will not be rockets supporting the whole of the interplanetary ship, but built-in rockets pushing the ship forward will be used to leave the Earth['s] atmosphere and to travel to other planets" [1, p.263]. It contributes to a lesser launching mass and a more simple fulfillment of the space exploration program. To some extent Tsander's ideas have been used in the shuttle spaceships. Although Tsander agitated those ideas, he paid his main attention to thorough theoretical researches in two fields, i.e., astrodynamics, and the theory of the liquid-propellant rocket engine.

In astrodynamics Tsander made a rather thorough research of a large number of problems connected with interplanetary flights within the solar system. We can freely assert that Tsander had analyzed all problems which were tackled by those who provided ballistic support to the interplanetary flights in the first two decades of the Space Age. His works in this field are characterized by completeness and a desire to tackle all astrodynamics problems which may arise in interplanetary flight.

Tsander began his research with the discussion of "the flight routes, additional speed which the rocket must give to the interplanetary ship, and the flight duration" [1, p.277]. He concluded that to save energy in interplanetary flight, one must take off in the direction of rotation of the starting planet to get to the outer planets, and in the back direction—to go to the inner planets. Tsander took into consideration both the ellipticity of the planets' orbits and continuous changes of their inter-locations. Actually he analyzed the problem of the best flight trajectiles and set a problem which is nowadays called the selection of expedient dates for launching. The trajectiles correction drew the special attention of Tsander. He underlined the importance of this problem, especially when coming up to the destination planet. The additional speed quantity, and the number of combinations of navigation changes were also determined. Besides, Tsander analyzed methods of gravitational maneuvers both for: the deviations from the route; and, for the increase of kinetic energy during the check flights of the planets; [He] also studied a problem of inter-planetary flights returning to the Earth in a number of years. The works mentioned above included the rudiments of space navigation. In particular, Tsander said it was possible to determine distance to a planet by measuring the planet's visible diameter. The results of Tsander's works became useful, and 1959 witnessed the first gravitational maneuver, when the *Luna 3* station made pictures of the back side of the Moon.

Being a specialist in the field of aviation engines, and clearly understanding that practical exploration of space had to be started with the creation of the liquid-propellant rocket engine, Tsander paid much attention to the theory of the LPRE. Tsiolkovsky only outlined the LPRE's design and possible propellant mixtures. Tsander worked out detailed methodology of the engine thermal account, including measuring temperature combustion with the consideration of dissociation, determining the nozzle shape and dimensions, combustion exhaust speed, and combustion chamber wall temperatures, and their cooling.

Thus Tsander's works are a great step towards the realization of space exploration with the help of rockets.

The works of Yu. Kondratyuk were also devoted to the implementation of the same ideas, but they were of quite another character. Kondratyuk was of the opinion that space systems were feasible at that time's stage of technical development. He wrote that he had got main results "not in the form of theoretical fundamentals, . . ., but in the form of a project, the realization of which is possible presently" [1, p.537]. But Kondratyuk was aware that the initial steps in that field could not but be moderate. That was why he limited himself to the immediate tasks, i.e., the problem of making the Earth's satellites and of reaching the Moon. In comparison with Tsander, who deeply studied several, to his mind, of the most important problems, Kondratyuk's researches were less detailed, but tackled a wider range of questions. His works seem to get the necessary results by the simplest means, and therefore in the shortest time. Let's take the launching problem, for instance. In the search of ways to lessen the launching mass, Tsiolkovsky thought of a rocket speed-up route over the Earth's surface, Tsander—of a rocket-plane design, and

Kondratyuk suggested a start of a multi-stage rocket directly from the Earth, fully aware that his idea demanded great launching masses, but it was the simplest one.

His works embraced almost all facets of space technique, which could be foreseen at the beginning of the present century, but did not give a systematic narration of the problems and their solutions. They "took out" separate questions for which Kondratyuk felt apprehensions that they would become crucial for the practical realization of this projects. This fact led to a seeming "inaccuracy" of Kondratyuk's narration.

When speaking of the goals analyzed by Kondratyuk, I'll mention only those which were not present in Tsiolkovsky's and Tsander's works: i.e., I'll try to estimate the new brought by Kondratyuk to the fundamental space science. Kondratyuk did not know the works of Tsiolkovsky and Tsander and came to the same results anew, but we will leave these results aside. It is not a problem of priorities and possible influence of the space pioneers on each other, but a sum of knowledge and ideas available by the early 1930s, which is of special interest.

As far as rocket engines are concerned, it's worth noting a relatively low interest of Kondratyuk for them. He tackled mostly purely engineering problems, such as cooling of the chamber and nozzle, best fuel mixing (complete and safe at the same time), fuel supply to the combustion chamber. He noted to use turbo-pump injection, suggested a staggered arrangement of the fuel and oxidizer injectors, recommended engine cooling by fuel components, and marked the importance of preliminary experiments in that field.

Analyzing the possibility of a relative lessening of the rocket passive mass and of a corresponding increase of the fuel relative storage, Kondratyuk introduced the concept of "a proportional passive," which is critical nowadays for weight analysis. To solve the problem of temperature conditions in the spaceship, he suggested a multi-stage, screen-and-vacuum insulation, which is being widely used presently. Kondratyuk emphasized the simplicity and low weight of such a system, and clearly realized that it would be multipurpose, i.e. be used both for heat preservation inside the ship and Sun overheat defense. For cosmonauts' safety during take-off, Kondratyuk invented seats which enabled the pilots to overcome the load factor, thanks to the seats' individual adjustment. It is common knowledge that such seats are used in modern spaceships.

Kondratyuk paid special attention to the flight control problem. He conceived the rocket control system, noting that flight control ought to be automatic and ruled by signals from two free gyros with mutually perpendicular angular momentum vectors. He also thought that the control system had to include a seeming acceleration transducer and an integrator of its signals, which would control the liquid-propellant rocket engine thrust. This is a description of a rocket control system characteristic of the carrier-rockets at the beginning of the Space Era.

The reentry problem was also solved in the simplest way, and that's why it became an actually realized form. Kondratyuk suggested that the reentry cell should be protected by a heat shield to ensure a big angle of attack (about 40°). At the same time, the heat shield serves as an aerodynamic surface, producing a resistance force and a lateral force. The latter can be directed both up and down, making rotations in roll. Emphasizing the necessity of control in roll (but not angle-of-attack control, about which Tsiolkovsky and Tsander wrote), Kondratyuk was of the opinion that such a system was necessary to ensure heat protection of the reentry cell. According to Kondratyuk, flight control must be automatic and use signals from two free gyros. Parachutes are used for landing. In general, this is how Soviet and U.S. flight control systems have been operating up to the present time.

As for the methods of cosmonautics, it's Kondratyuk's great merit to determine that people ought to use artificial satellites of the Moon and other planets (but not the Earth's ones) as their intermediate bases. Besides, he stressed that it was worth using a special landing module, which could depart the intermediate base to get to a planet's surface and return [1, pp.532, 589].

Kondratyuk's ideas about the goal of cosmonautics were also practically based. Considering colonization of the Solar System possible, Kondratyuk, at the same time, wrote about more "beneficial" tasks for the initial period of determining the main aim of cosmonautics. Those aims could be more useful for mankind.

To sum up the content of this paper, I'd like to say that as a result of deep researches of the space technique pioneers, first of all, of Tsiolkovsky, Tsander, and Kondratyuk, by the late 1920s and early 1930s, this country had achieved a clear understanding of the ways to make spaceflights. The fact that not all materials were published at that time, and some part of them remained in the personal archives of the authors, does not make my statement less convincing, because those three persons were in close contact with groups of enthusiasts who started practical work to make rockets. And moreover, Tsander, together with Sergey Korolev, was at the head of one of those groups. These circumstances did actually lead to the fact that the influence exerted by the space technique pioneers of the 1930s, over those who started at that time to realize dreams of space exploration, in practice, was greater than the influence of their published works only.

Looking back at the 20-year-long Space Era since the first artificial satellite's launching, one cannot help admiring how exactly the space pioneers conceived the ways to the realization of their ideas. The only thing they could not foresee is a broad utilization of radio and electronics, without which every modern spaceflight is absolutely unbelievable. But it is understandable, because there were no radar measuring methods, no electronic control devices, and space radio communication seemed doubtful because of a gas layer called "Heavyside layer" reflecting radio waves. The 1930s saw electronics and radio techniques in rockets (Korolev's rocket 20I). It is understandable now why the problems of navigation and communication were tackled, in the papers mentioned above, on the level of optics of that time, and why the pioneers paid so much attention to optical devices, mainly to various telescopes, as the main means of space communication and navigation. Although radio engineering means and methods helped a great deal to solve communication problems, the ideas of the possibility and expediency of using optical devices in space are still important, and such devices are being widely used in cosmonautics.

In the light of the data given above, it is possible to assert that the Space Era, the beginning of which is truly attributed to the works of the 1930s and 1950s, goes back to the earlier period not only emotionally. The earlier period works include not only ideas of the space exploration goals, not only of a general possibility to fly into space, but also a number of clear technical suggestions for the most expedient and shortest ways to implement the oldest dream of mankind.

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