ISSN 1019-3316, Herald of the Russian Academy of Sciences, 2013, Vol. 83, No. 5, pp. 422–428. © Pleiades Publishing, Ltd., 2013.
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To answer the question about the present and future of the space industry, one needs something more than knowledge about its individual aspects. The author attempts to approach the problem from the positions of systems analysis with account for the ideological grounds and history of space activities in Russia and abroad, comparing its current interpretation with the initial goals posed by leading theoreticians and practitioners who stood at the cradle of the space exploration era.

DOI: 10.1134/S1019331613050018

Space Activities in Russia: Problems and Prospects

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Owing to its historical past, scientific potential, rich mineral resources, and vast territory, Russia was destined to be a leading space power. Nevertheless, the preservation of this status, acquired at the dawn of the space exploration era, is hindered by the stagnation of space activities, caused both by the funding shortfall in the near past and by a number of present-day factors. The understatement of the significance of space activities for social progress, an insufficient understanding of the role of its scientific component, an incorrect choice of orientation points, the absence of systematicity and effective organization, and the politics of commercialization have led to extremely unsatisfactory results in the early 21st century. The problem requires detailed, deep, and, most importantly, systems analysis, which should obviously begin with determining the content and purposes of space activities.

THE ESSENCE OF SPACE ACTIVITIES

It is impossible to understand the essence of space activities without characterizing its scientific basis—cosmonautics—in the first place.

Cosmonautics, whose basics were laid by K.E. Tsiolkovskii [1], synthesizes knowledge in natural, engineering, and social sciences. Its scope includes scientific–technological, biomedical, and juridical problems. The synthetic property of cosmonautics is determined by its new natural environment, in which we are to solve its main task—the spatial expansion of the social sphere; this returns us to the worldviews of Russian cosmists, who believed that it was possible to develop human life unrestrictedly in space and time.

In his concept of cosmonautics, Tsiolkovskii included the thesis about the direct presence of man in outer space as a necessary condition for cognizing the laws of nature and for possible anthropogenic processes in the universe. Only intelligence, which is a biological phenomenon, can organize human existence in outer space. As for automatic devices, they are essentially an effective addition.

Emphasizing the problems of man in space, S.P. Korolev identified cosmonautics with crewed spaceflights [2]. At the same time, he paid due attention to robotic spacecraft (SC) as a means of accomplishing the goals of cosmonautics. This is how the broad interpretation of the notion *cosmonautics* has developed, including the theory and practice of crewed spaceflights, as well as studies on space habitation using robotic SC.

After the first crewed spaceflight, cosmonautics acquired millions of adherents. People became confident in their potentialities, unlimited by the Earth's gravity. Spaceflights had a colossal sociocultural resonance. The Soviet Union at the state level became aware of not only the scientific but also the political, military, and later socioeconomic significance of cosmonautics.

Soon after launching the first artificial satellite into orbit, the Soviet Union performed a number of missions to the Moon and the nearest planets using robotic spacecraft. This laid grounds for the use of spaceflights for basic studies of the properties of outer space in the interests of astrophysics, planetology, and earth sciences.

With a slight time lag, cosmonautics (astronautics) developed in the United States as well. Simultaneously, the pragmatic Americans started using outer space to solve terrestrial military and civilian tasks. This time, the Soviet Union followed the example of the United States and began launching artificial satellites to service radio communication, hydrometeorology, radio navigation, and remote sensing of the Earth.

This was how the sphere and trends of space activities were established. The first official mention about it in international documents appeared in 1961 in the UN General Assembly resolution of December 20,

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1961, entitled International Cooperation in the Peaceful Uses of Outer Space. An adequate interpretation of space activities is provided in US regulatory documents, meaning any activities related to access to outer space or realized directly in outer space, through outer space, and from outer space to achieve certain goals. The goals, global by definition, are elaborated in the process of space activities, while means for accomplishing them are created in solving scientific–technological problems of cosmonautics.

Space activities are traditionally divided into three areas:

• crewed spaceflights, which solve the main task of cosmonautics—ensuring the functioning of humans directly in outer space;

• space robotic SC-involving studies, including studies of outer space as a possible habitation and basic studies of space properties; and

• the use of space properties for producing and propagating (transporting) information, energy, and materials, i.e., for practical purposes dictated by requirements arising in the conditions of planetary existence; this application of cosmonautics forms the market of space services.

The stratification of space activities is determined by its logic. The priorities of space activities are crewed spaceflights and space research, which form its basis. However, modern Russia places the priority on space utilization, which has become one of the main causes of its stagnation.

COLLISIONS IN COSMONAUTICS

Today's problems and prospects of space activities correlate to a degree with collisions in the history of cosmonautics.

Cosmonautics originated in Russia, which is explained by the socioeconomic and sociopolitical features of Russian society [3]. Up to its disintegration, the Soviet Union was a recognized ideologist of cosmonautics. Even despite the collisions associated with the "lunar" program, Americans recognized that the author of the lunar project was our compatriot Yu. Kondratyuk.

The first project of a crewed mission to Mars was also developed in the Soviet Union. In the late 1950s, simultaneously with the preparations for Yu.A. Gagarin's flight, Korolev, implementing Tsiolkovskii's ideas about "life outside the Earth," initiated the Martian project. In accordance with the resolution of the Central Committee of the Communist Party and the USSR Council of Ministers of June 30, 1960, the development of the superheavy launch vehicle N-1 and the design of an interplanetary crewed complex (reusable space transportation system) with a mass of 60–80 t officially began [4]. Korolev failed to implement the Martian project because of N.S. Khrushchev, who directed him into the lunar race.

In 1966, the great scientist, engineer, and visionary—realist died, and cosmonautics lost its world-scale leader. Korolev's associates decided to abandon the Martian project and initiated the short-term creation of a long-term space station (DOS) instead. The politically attractive proposal was supported at the highest level. This was to an extent prompted by failures of the N-1 carrier. Khrushchev's successor L.I. Brezhnev proclaimed long-term space station–based studies the mainstream in outer space exploration.

The DOS project was a technical novelty, but it delayed for decades the spatial expansion of space activities because the DOS design did not envisage crewed flights to deep space, limiting them to low near-Earth orbits. From 1971 through 1986, seven DOS Salyut specimens were manufactured and operated, and from 1986 through 2000, the first international space station Mir worked in orbit.

Following the Soviet Union, the United States began exploiting near-Earth orbits by crewed facilities. It implemented the inefficient Space Shuttle reusable transport system project, which was based on a forecast of the exponential growth of cargo flows along the Earth–space–Earth paths. Only 135 flights, including 14 dockings with the International Space Station (ISS), were accomplished in 30 years; the Hubble Space Telescope was serviced.

In 1987, instead of the N-1 carrier, V.P. Glushko created the superheavy launch vehicle Energia with the same carrying capacity (~100 t) and the Buran spacecraft, analogous in function to the Space Shuttle but surpassing it in design.

In 1998, the United States took advantage of the period of reforms in Russia, seized the 30-year-old initiative, and with the participation of Russia built the International Space Station (ISS) instead of the DOS Mir. This station, which is essentially a bulky biomedical laboratory, continues to operate and supports the development of promising space technologies in Europe and Japan. The United States and Russia receive political dividends, Russia receiving commercial profit as well.

The early 21st century saw advance in global cosmonautics: it returned to Korolev's plan to fly to Mars, but this time the leader was the United States. President B. Obama, characterizing the space policy of his country, noted that, to ensure long-term efficiency of the space program, it was necessary to remember about the coming great adventures and discoveries. He stressed the necessity to revive interest in the space program, which had been typical not only of professionals but also of the public.

Against the background of such statements, the United States began financing the Martian project, envisaging the creation of an SLS carrier in 2017 with a carrying capacity of 70 t with a further increase up to 130 t and a first-phase cost of $35 billion, as well as the creation of the MPSV Orion spacecraft with a mass of 25 t. It is planned that the MOSV Orion spacecraft will first be put in orbit in 2015 using a Delta 4 carrier. The roadmap of a crewed spaceflight to Mars was published. The project is gradually becoming international. For example, the European Space Agency will take part in the development of the Orion Service Module.

In Russia, the ISS program preserves its long-term status, which is recorded in one of the main documents of the target-program planning of space activities approved by the Russian president on April 24, 2008, and entitled The Fundamentals of Policy in the Sphere of Space Activities until 2020 and Beyond. The SC Soyuz is also being modernized and replicated with an eye to income from the space market (until new US spacecraft appear). Another document, the Russian state program Russia's Space Activities for 2013–2020, implies that the planned measures on the development of new technologies for crewed flights to deep space will largely be implemented only after the completion of the program.

The 1990s changed the mentality of Russian society, and this led to ambiguous responses to the challenges that cosmonautics was facing in the early 21st century. (This is outlined in the Declaration of the Heads of the 25 Space Agencies Summit, held in Washington in 2010.) Some Russians, absorbed in seeking "daily bread," think it reasonable to limit space activities to space utilization. Others see the prospect (until 2050) in colonization of the Moon and its possible use as an intermediate link for future flights to Mars [5–7]. However, they leave out of account the lack of goals in the utilization of the Moon, as well as the fact that the track of the flight to Mars will most likely run through a Lagrangian point.

There is also a third opinion claiming that the country's life activities and its authority in the international arena make crewed flights to Mars topical for exploration purposes [4]. There is no doubt that accomplishing a superobjective like this will require several decades, but the main point is that it can revive faith in cosmonautics as a force that guarantees progress for human civilization.

Turning to the above-mentioned program Russia's Space Activities for 2013–2020, one can conclude that the first point of view dominates at the state level. Argumentation in its favor rests on the thesis about the shortage of funds for financing crewed flights to deep space and on the desire to commercialize space activities. However, this argument does not seem convincing. The state has sufficient reserves to increase the financing of space activities. This is proved by expenditures for the construction on Rybachii Island and for sites for international sport competitions in 2014 and 2018, as well as by examples of inappropriate expenditures within the Ministry of Defense, the Ministry of Agriculture, the Federal Space Agency (Roscosmos), and other structures.

Moreover, the allocations for space activities in the amount of $70 billion, planned until 2020, exceed two times the cost of the first phase of the US Martian project. Of course, this amount is insufficient for the entire space activities with account for implementation of a comparable project, but it is evidently excessive if such project is absent.

We must also bear in mind that the project of a crewed flight to Mars can become international on the ISS model. In this case, we need political will and an intellectual and material contribution to the creation of respective technical means.

SPACE ACTIVITIES AT THE BEGINNING OF THE 21st CENTURY

Space activities continue to develop in the world, but its growth rates have decreased. For example, in 1963–1969, NASA received 5.5% of the US expenditure budget, while in 2012, only 0.47%. Nevertheless, participation in space activities today is an indicator of a state's international status. More than 130 countries use the results of space activities, 40 of them creating their own space rocket equipment. About 1000 space vehicles function in outer space; the world space market is estimated at $150–200 billion. The financing of the civilian component of space activities of the leading space powers in 2012 reached $17.8 billion in the United States, $5.3 billion in Europe, $4.8 billion in Russia, $4.1 billion in Japan, and $1.04 billion in India (there are no data on China). Most budgetary allocations fall on crewed programs: for example, the respective share in NATO is almost 80%.

China—the third country that can send humans to space using exclusively its own resources—is becoming an increasingly noticeable participant in the club of leading space powers. China also demonstrates that it can perform serious space studies. A bright example is the unique mission of the Chang'e 2 interplanetary probe, which took pictures of the lunar surface from a selenocentric orbit and then left for the L2 Lagrangian point. After this, it came close to the asteroid 4179 Toutatis and took pictures of its surface with a resolution of 10 m. With regard to the number of launches of carrier rockets, China is in the second place, close to Russia and before the United States.

The active participation of Japan, which has accomplished, despite quite moderate financing, a number of unique projects, in space activities deserves attention. In particular, the Japanese interplanetary probe Hayabusa became the first spacecraft to deliver to the Earth soil samples from the near-Earth asteroid

25143 Itokawa. IKAROS, which has been functioning in space since May 2010 and is the first spacecraft with a solar sail in the history of cosmonautics, creates preconditions for taking up fundamentally new displaced "levitated" orbits. Japan has also managed to place into a sun-synchronous orbit the first greenhouse effect space researcher in global practice.

As for Russia, space activities in our country are now at a level that does not correspond either to the scientific–technical potential formed in the Soviet period or even to the funds allocated today. Under stagnation in crewed spaceflights, Russia has no spacecraft for basic research in near-Earth or deep space. Meanwhile, all leading space powers, except for our country, perform distant and contact observations of Mercury, Venus, Mars, Saturn, the Moon, and other bodies of the Solar System, including the Sun, using their own domestically developed spacecraft.

The share of Russia in the world space market is ~1% despite all calls of our authorities for the commercialization of space activities. This seems to be a result of underestimating the role of space research and manned flights, which became a locomotive of advanced space technologies and information technologies. In the sphere of space use, our country occupies a good place only in navigational–temporal support. Russia became the second country to have its own global navigation satellite system, GLONASS, developed in the 1980s.

In the sphere of satellite communication support, Russia owns about 10 spacecraft out of the 300 exploited by the international fixed satellite service. Russia merely modernizes and replicates radio communication spacecraft. (Remember that the Soviet Union, with the participation of the author of this article, created the first satellite systems of personal radio communication and direct TV broadcasting in the world practice.)

The international Earth's remote sensing orbit group includes about 130 spacecraft that generate information in wide optical and radio ranges with a resolution from several tenths of a meter up to several kilometers. Russia has two to three spacecraft in orbits and is developing numerous contradictory projects, such as Stroi, Obzor, and Arktika. The participation of Russia in the construction of scientific and technological microsatellites is also minimal. Finally, the fact that Russia is the leader in the market of launch services is neutralized by the small share (2.5–3%) of this sector in the total scope of the world space market.

SYSTEMATIZATION AND GOAL SETTING OF SPACE ACTIVITIES IN RUSSIA

It is important to understand that insufficient state investment is not the sole and possibly even not the main cause of stagnation in the Russian space industry. A much greater threat is the absence of a systemic idea, although Tsiolkovskii laid the systems approach as the methodological ground of cosmonautics. In his works, the scientist consistently followed the principle of the integrated cognition of objects, processes, and phenomena in space [1].

From the positions of the systems approach, the priority in space activities is goal setting (the elaboration of goals). This priority is obvious because, according to N. Wiener, it is more important to know what to do than how to do it. In Russia, goal setting is in accordance with the Fundamentals of Russian Policy in the Sphere of Space Activities until 2020 and Beyond. The text of this document logically states that Russian state interests in space research and use are the following:

- preserving its status as a leading space power,
- using space facilities to ensure national security and to develop the socioeconomic sphere and science, and
- widening the presence of Russian organizations in the global space market and developing the internal market of space goods and services.

At the same time, the purposes and priorities of space activities, as they are stated in the Fundamentals, do not guarantee that these interests be observed to the full. This conclusion follows from the fact that this document assigns a secondary role to crewed flights and space research. The adopted prioritization deprives space activities of development prospects and deepens its stagnation. According to global experience, the status of a leading space power implies ambitious crewed spaceflight projects, which have been the stem of space activities since the beginning of the space exploration era. Such projects included the first manned spaceflight, the lunar program, long-term space stations, the Space Shuttle, and the ISS. They have determined the innovation character of space activities and stimulating progress in many spheres of science and technology. The Russian authorities, questioning the topicality of ambitious projects, prioritize other projects, such as the Angara rocket family, the Vostochny Cosmodrome (Eastern Spaceport), GLONASS, and the like, which will be discussed below.

The absence of the systems approach in elaborating the goals of space activities is evident from one of the priorities envisaged in the Fundamentals—"ensuring guaranteed access to space for Russia," supplemented by the plan to create a new spaceport on Russian territory, which is also viewed as a priority. First, the thesis about guaranteed access to space for Russia was taken out of the context of a wide scope of problems solved by space means to maintain Russia's space activities. Second, target tasks of space activities, including free access to space, should be accomplished in interconnection with each other through the creation of transportation facilities with respective launch complexes. At the same time, we should answer the following traditional questions strictly in the following succession: Where to fly? Why to fly? How to fly? And from where to fly?

To preserve the status of a space power, Russia needs a superheavy launcher, but the Roscosmos managers go on repeating that we do not need a new rocket and that we will fly by what we already have [8]. Hence, the question arises: Why do we need the new spaceport? It is created with a launch complex of the modernized Soyuz 2 carrier—a clone of the rockets on the Baikonur Cosmodrome, the Plesetsk Cosmodrome, and in the Guiana Space Center near Kourou in French Guiana. Meanwhile, $13 billion is envisaged for the construction of the Vostochny spaceport, costing 30% of the American Martian spaceflight roadmap. By the way, these funds are sufficient to rent the Baikonur Cosmodrome for several decades.

The motives for the creation of the Vostochny Cosmodrome are clearly political and correlate badly with the topical tasks of space activities.

Apparently, purpose-setting principles in Russia's space activities require serious consideration. We cannot but agree with D.O. Rogozin, who stated in August 2012 that it was necessary to formulate our own interests and strategic goals in space activities. Appealing to the systems approach, Rogozin proposed to choose a superobjective as a guide and implement it even if it seemed fantastic today.

COMPLEX TECHNICAL SYSTEMS IN SPACE ACTIVITIES

Judging from the systemic positions, it would be efficient to explicate the scientific–technical component of space activities through a system of actions aimed at the creation and targeted use of a certain class of complex technical (space) systems.

The overwhelming majority of the projects that have been implemented since the beginning of the space exploration era are essentially space systems. A space system (SS) is an ordered set of interconnected technical means (components), mostly extraterrestrial. The integrative properties and functions of this set are targeted at accomplishing the goals of space activities. Space systems are created using state-of-the-art space and information technologies on the methodological basis of systemic engineering [9]. Just like any complex system, a space system has a set of properties (characteristics) that guarantee its existence at all stages of its life cycle [10, 11]. Such characteristics are integrity, purposefulness [12], acceptability, continuity, compatibility, dynamism, and others.

The space systems recognized in Russia as priority projects are largely developed with violations of the systems approach principles. For example, the GLONASS space system is characterized by purposefulness and integrity, but it is only partially correct with regard to acceptability and compatibility. The military component of the acceptability of this SS does not raise doubts, while the civilian one is debatable. The state of the electronic industry and management in the country will hardly allow GLONASS to become a full-fledged participant in the world market, which is largely monopolized by the United States. In addition, within the Asian segment, a new competitor in the person of China and its system Beidou has appeared. To ensure national security with account for the compatibility of GLONASS with GPS in commercial use, it is admissible to reduce the SC orbit group by 25%. The GLONASS composition is also excessive because of functional augmentation complexes and fundamental support, absent in GPS. In this situation, it is advisable to use the domestic experience of designing the first navigation satellite system in the world practice, Tsiklon, Russia can develop a GLONASS-based satellite system of controlling mobile objects in all terrestrial media, which will allow our country to occupy the currently empty niche in space use.

Another example of the absence of the systems approach is the Angara space rocket complex. The presidential decree on its creation dates back to 1995. According to the technical specification, it is designed for solving a wide range of tasks. The project is characterized by insufficient purposefulness, which manifests itself in the lack of specific tasks and, most importantly, the task to perform crewed spaceflights—the most labor-consuming part of space activities.

The Angara space rocket complex includes a set of launch vehicles of light, medium, and heavy classes. The project is actually commercial: its authors tried to enter the space launch market but repeated the mistake of the Space Shuttle creators, suggesting that Earth–space traffic will grow exponentially. Both the dislocation and the number of launching sites were determined incorrectly. The acceptability of the complex turned out to be questionable: 17 years have passed, but the Angara space rocket complex remains unclaimed thus far and is still at the developmental testing stage. The first flight tests are planned for 2014, but Roscosmos cannot answer the following simple question: What is the Angara rocket complex designed for?

It is strange that this project was approved at the highest level, although it lacks the main attributes of systematicity. Moreover, the creation of the Angara rocket complex, along with the GLONASS program, topped the agenda of Russian space activities. The only way out in the current situation seems to be the development of a superheavy-class launcher, which Russia really needs, on the basis of the Angara rocket complex perhaps, or upon recovering the Energia carrier technology.

As is obvious from the considerations presented above, the Vostochny Cosmodrome project does not correspond to the systems approach principles either. Finally, noteworthy is the project on the creation of a space transportation module (STM) with a megawatt-class nuclear power propulsion unit (NPPU), included in the presidential program of the country's economic modernization in 2010. This essentially pioneering project is targeted at crewed flights to deep space, including Mars, and its implementation may yield revolutionary transformations in cosmonautics because the use of nuclear power can change qualitatively the level of logistic missions [13]. However, the project implies solving a complex of unique scientific, technical, and economic problems requiring significant research efforts. From the engineering point of view, it is difficult to imagine how the developmental and design work on the space transportation module could begin without research and the systemic coordination of expeditions. Since the characteristics of integrity, acceptability, and continuity are absent, the implementation of the project in the first half of the 21st century seems improbable and perhaps deprived of practical significance. According to the estimates of a number of experts, nuclear power will be necessary for crewed flights to remote planets of the Solar System, as well as beyond it, while flights to Mars and near-Earth asteroids in the foreseeable future will be accomplished using solar energy and chemical fuels. It is in this direction that the United States is developing its space program.

Our analysis shows that a systemic disadvantage of many space stations developed in Russia is their large scale, which threatens their integrity. The space monitoring system (SMS), the multifunctional aerospace monitoring system (MASMS), the regional multipurpose space system Arktika (Arctic), and the Emergency Road Assistance ERA GLONASS system can also be attributed to such space stations.

THE ORGANIZATION OF SPACE ACTIVITIES

The creation of space stations and their use according to the intended purpose are within the scope of space activities. Space activities with a set of properties (characteristics) of a complex system are a purpose-setting system and form the purposefulness of individual space stations.

The state of purpose setting in Russia's space activities is described above. As for acceptability, this characteristic correlates with purposefulness weakly in this case, because federal space programs are developed for a period of 10–15 years and plans of their financing, for three years. The above state program, Russia's Space Activities for 2013–2020, which poses no tasks on ensuring national security, demonstrates a lack of integrity.

One can judge about continuity in space activities by the state of the art, reliability, and quality of space equipment under development, whose characteristics, just as before, are ensured by the professionalism (education) of its creators, the country's scientific potential, and the participation of military specialists in the process. However, although the Soviet Union occupied leading positions in key fields of science [14], Russia is behind the leading space powers with regard to its share in world expenditures on science (2% against 30% in the United States, 24% in Europe, 14% in China, and 11% in Japan). The share of R&D costs in the structure of Russia's GDP is 1% against 2.8% in the United States, 2.0% in Europe, 1.7% in China, and 3.5% in Japan.

Design thought is degrading: the school of chief designers, founded by Korolev, has vanished. Since the death of M.V. Keldysh, the Russian Academy of Sciences has been passive relative to cosmonautics, limiting its interests to space research. The decisions that caused the withdrawal of military specialists from participation in space activities were unreasonable. With the beginning of the transformations of the 1990s, the Soviet system of quality and reliability control was displaced by insurance companies.

Space activities as a system should be protected against destruction by its organization, but it is weakly developed in Russia, lacks a clear hierarchical pattern [15], and is, in fact, a split hierarchy. In a market economy, the Military–Industrial Commission under the Russian government has none of the authority enjoyed by the previous Commission on Military–Industrial Issues under the Presidium of the USSR Council of Ministers. Space activities are managed (coordinated) at the second level of the organizational hierarchy: by Roscosmos in the interests of science, technology, and different economic branches and by the Russian Ministry of Defense in the interests of defense and national security, as well as jointly by these departments with regard to the implementation of state policy in the sphere of space activities. The third level is mainly represented by open joint-stock companies with 100% state participation. Note that Roscosmos also acts as a controller of operators in the space industry, which under market economy conditions generates monopoly and corruption.

The current state of space activities indicates its organizational inefficiency. A number of space equipment breakdowns brought the issue of reforming the rocket–space industry to the government level. Proposals are considered on uniting the industry's enterprises into holding companies, changing the functions of Roscosmos. No doubt, the space industry does need reform, but it should mandatorily be preceded by setting the goals and priorities of space activities.

In conclusion, I will venture to state that global space activities contribute significantly to the development of society in the early 21st century. At the same time, the current level of space activities in Russia does not allow it to remain a leading space power.

To rescue domestic space activities from stagnation, it is necessary to change state policy with regard to setting the goals and priorities of these activities. Investments in it are promising only if focused on crewed programs and space research. The efficiency of space use is determined by the development of the scientific basis of space activities—cosmonautics. The presence of an ambitious spaceflight project based on a superheavy launcher not only constitutes a necessary condition for the development of the space industry but also ensures a high rating for Russia among industrially developed countries. This should be understood at the state level.

In addition, to hold the existing positions and to occupy a good place in the world market of space services, it seems purposeful from the systemic point of view to focus space activities on two-to-three priority projects and to occupy a niche in space activities. The complex exploration of minor bodies of the Solar System, the satellite system of controlling mobile objects in all terrestrial media, and the satellite system of monitoring ocean life could become such projects.

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Translated by B. Alekseev