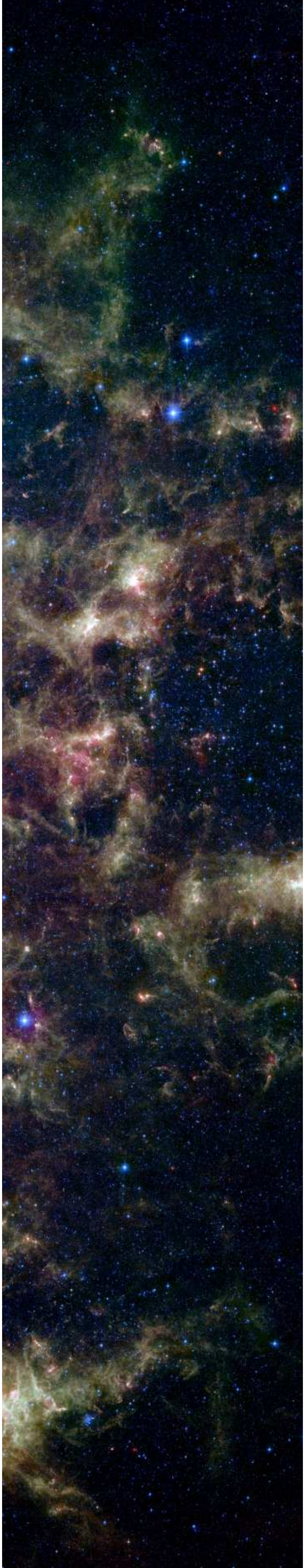

Strategic Directions and Priority Areas of Development for "Space Technology and Telecommunication" Cluster of the Skolkovo Foundation

2012

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The present document describes the results of methodology development and evaluation of strategic directions and priority areas for "Space Technology and Telecommunication" Cluster of the Skolkovo Fund. The first iteration was obtained by ST&T expert group with assistance of leading space R&D institutes using the Federal Space Agency materials. The Strategic Directions will be subsequently specified under the foresight research based on the contract between the Skolkovo Fund and one of the leading R&D and consulting organizations in the field of space activity and its results' commercialization.

The Glossary can be found at the end of the document

EXECUTIVE SUMMARY: PRIORITIES

ST&T Cluster ensures search for, attraction and selection of potential subjects of innovative process in the field of development and target use of spacecrafts operation and diversification of rocket and space industry potential, facilitates their cooperation and provides the environment for full cycle innovation process establishment, based on the Strategic directions and priority areas of development, initially defined by this document and regularly updated considering opinion of sci-tech and business community that is identified in process of foresight procedure.

At the moment, the Cluster finds it necessary, along with comprehensive support for innovative activity of the Skolkovo Fund participants and applicants, to focus on proactive implementation of several priority areas which particularly include:

- Establishing national infrastructure of full cycle microsatellite technology which involves leading universities.
- Establishing national infrastructure and business development in the field of manned suborbital flights.
- National business development in the field of spacecraft target equipment and electronic components base design and manufacturing.
- Establishing specialized outsourcing engineering and consulting centres in the field of applied cosmonautics and domestic companies competency development
- SkolkovoTech curriculum development, establishing multilayer educational environment based on the lead in the field of space oriented education along with distance and network components
- Establishing legal regulation field that regulate business activity and public-private partnership in the field of cosmonautics.
- Fundamental and applied research in the field of aerospace technology.

I. STATUS

National space activity is an indispensable part of scientific-technical and spiritual heritage of Russia. Our country has been taking one of the leading roles in space exploration and utilization for more than half century. Up to the moment, the Russian cosmonautics still remains one of the fields of national competitive advantage, defining our place among economically developed countries in many respects.

Space activity development, allowing to strengthen defensive power, accelerate the economy modernization process, provide the effective science, technology and social development, is one of the key factors in the country economical and social development, growth in the living standards and providing national security.

For the continental state having vast territory with reach mineral reserves and unevenly developed communications, the spacecrafts employment for the purposes of communication, TV and radio broadcasting, Earth remote sensing, resources and objects monitoring, navigation and cartography, it is the only way to provide a solid foundation for territorial and system integrity of the country, informational and spiritual unity of its multinational people. The cosmonautics and Russian space achievements enable us to be proud of our motherland

Finally, achievements and potential of scientific cosmonautics and implementation of human space exploration programs facilitate the development of scientific knowledge and broaden available horizons of unlimited space for the mankind, thus determining our prospects as a global community of the Earth people. The Russian space activity is by far not the last thing that determines our role as a rightful active participant in the global initiatives of the mankind.

Today, the national cosmonautics encounters complicated challenges of sci-tech, economical and institutional nature. A part thereof goes back to the overall economic situation in the country, and especially to 1990's collapse. Second, not least important is the fact, that in the process of economic environment changes the rocket and space industry was not prompt enough to provide pressing transformations and was developing inertly using the sci-tech momentum remained from the Soviet times.

As a result, the leading countries «left us far behind», and Russia virtually depleted the Soviet lead, but did not produce a new generation of space technology and facilities, an appropriate system of quality and reliability control, a national industry competitive advantage support and state order system. The discipline and responsibility level is unacceptably low.

One of the world best systems of scientific and technical education has been distorted, and the natural generational change in the industry did not take place.

Of course, the Russian cosmonautics still keeps its meaningful achievements. Russian spacecrafts provide the International space station existence, crew rotation and supply missions. Russian company supplies engines for American launch vehicles. Recently the first LV "Soyuz" was successfully launched at European Kourou space centre in French Guiana. We perform more than 40% of the space launches and take up a leading position on the global market. However, if we consider the global space market as a whole (including satellite communication, space-based Earth observation, and other applications) that had a total size of $200 billion in 2010, the Russian companies share is only 3 per cents. We should overcome this situation.

Without principal, maybe painful steps towards fundamental technologic and institutional reforms in the space sector, it is yet impossible to provide the further development of the Russian cosmonautics. In addition the national space activity should become a viable tool for innovative development, and the space facilities potential should benefit public and private users in all regions of the country.

Establishing an innovative ecosystem that is beneficial for business development and research in the priority areas, including Space technology and telecommunications, the Skolkovo Fund and its Space Technology and Telecommunications Cluster (ST&T Cluster) deal with the dual task: on one hand - to commercialize the potential and capabilities of rocket and space and allied industrial sectors in order to implement vertical and mass market business projects; on the other hand - to utilize the capabilities of innovative ecosystem and " maturing" here innovative businesses for solving development tasks in the field of national space activity and its sci-tech and human potential development.

Background retrospection

Over fifty years ago the Soviet Union launched the first space apparatus in 1957. So far over 6,800 satellites, manned spacecrafts, long-term manned stations and automatic interplanetary missions have been launched successfully.

The space projects of the USA, China, India and Russia (the USSR) are summarized in Fig. 1 and Table 1. The graph in Fig. 1 shows that the peak of space projects in Russia (the USSR) was from 1970 to 1991. The USSR used to launch about a hundred space vehicles every year. Afterwards, due to the known reasons, their number dropped abruptly so that Russia launched only 214 spacecrafts successfully during the first decade of the 21st century or slightly over 21 spacecrafts on the average per year.

During the space exploration until 2010 inclusively, Russia (the USSR) launched 3,479 space vehicles, 3,250 among them were successfully injected into the orbit. Thus, the launch reliability of an individual satellite equals 93.4% in Russia. The constellation of space satellites included 74 civil, double-purpose and military spacecrafts as of 31.12.2010. After the first launches the average active life (AAL) of Russian space vehicles kept growing and reached its historic maximum in the 90s of the last century. Yet, at present, there is a stable trend in satellite average life reduction that causes a considerable diminishing of Russian satellite constellation during the last decade.

The graph shows that in the 60s the USA used to launch about 70 satellites per year on the average. During this period American scientists and engineers perfected the technology of satellite manufacture extending AAL from 10 to 15 years; as a result, the USA reduced the launches twice down to 30 launches a year in the 70s. Exactly this average annual number of launches has been maintained by the USA during the last 30 years. The peak of satellite launches in the late 90s was caused by the development of the US low-orbit satellite communication systems (Iridium, Globalstar and Orbcomm).

Fig. 1. Number of satellites injected into orbit since 1957 until 2010

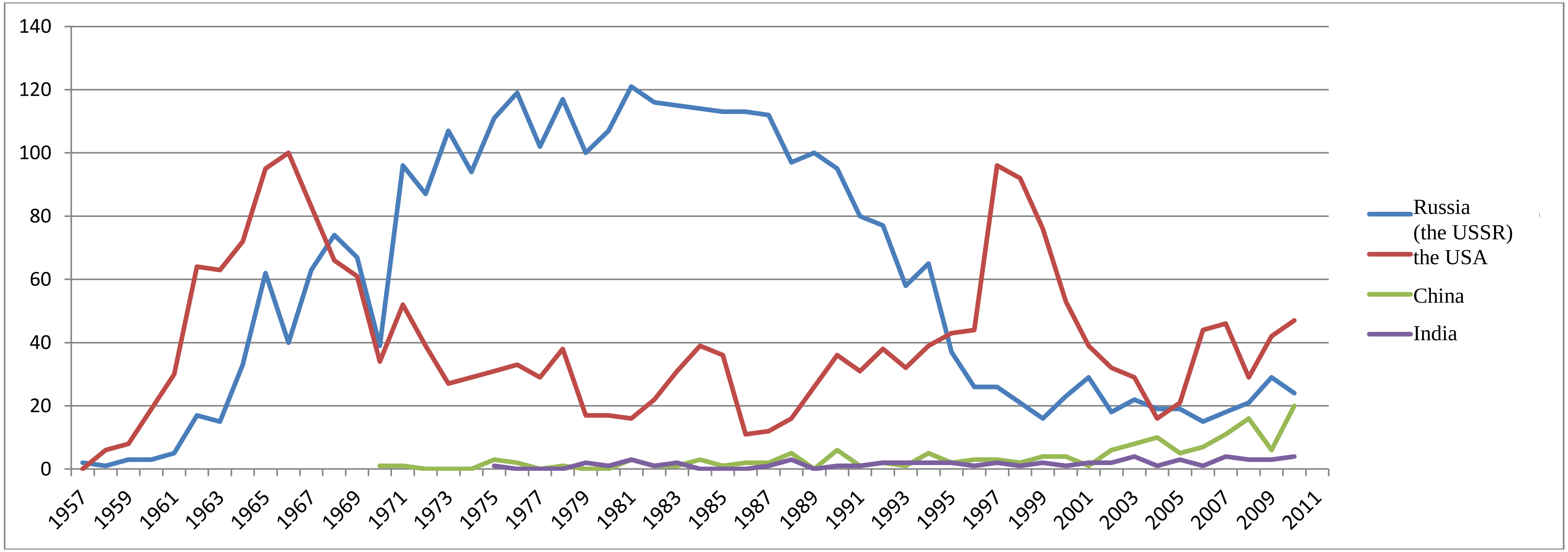

Table 1. Spacecrafts designed and injected into orbit by Russia (the USSR), the USA, China and India

Country	**Global**	**Russia (the USSR)**		**The USA**		**China**		**India**	
	1957 - 2010	***1957 - 2010***	***2001-2010***	***1957 - 2010***	***2001-2010***	***1970-2010***	***2001-2010***	***1975-2010***	***2001-2010***
Number of spacecrafts home designed and successfully injected into orbit, total	**6 853**	**3 479**	**222**	**2 402**	**372**	**147**	**87**	**58**	**31**
successfully	**6 264**	**3 250**	**214**	**2 147**	**344**	**138**	**87**	**53**	**27**
Number of spacecrafts operating in orbit as of 31.12.2010	**958**	**74**		**440**		**69**		**29**	

Throughout the space missions since 1958 until 2010 the USA launched 2,402 satellites for their own purposes, 2,147 of them were injected into orbit successfully. Thus the launch reliability of an individual US satellite equals to 89.4%. The actual US satellite constellation of civil, double-purpose and military satellites fulfilling specific tasks includes 440 space vehicles as of 31.12.2010. Note that the US enterprises manufactured over 300 satellites for other countries.

The present day

What tendencies characterize the modern progress of global space activity? The experts of the ST & T Cluster identify the following trends:

- Competition of space technologies at the mass market with alternative ‘ground’ solutions;
- The growing value of international cooperation while implementing space projects, first of all, the large-scale projects;
- Introduction of the purely private initiative into all segments of space technology;
- Reduction of the significance of such scenarios like outer space humanity expansion in the common thinking.

Various states demonstrate these tendencies with different intensity in various segments of the market of space products and services. Let us evaluate specific aspects governing the challenging problems of the cosmonautics in Russia.

The state-of-the-art of the Russian space activity is characterized by the competitive advantages of national launch vehicles, provision of the minimal country’s need for services of stationary space communications and broadcasting, completion of the GLONASS system satellite constellation deployment, full-scale fulfilment of Russian international obligations under the project of development and operation of the International Space Station.

However, facilities and technologies of space communication and broadcasting, hydrometeorological observation and remote Earth probing, orbital means of basic space research, personal satellite communications, relaying and rescuing of objects in distress lag behind severely.

What is happening in specific areas of Russian space activity?

Space communications and broadcasting

The problem of development and maintenance of modern telecommunication infrastructure in the Russian Federation can be solved only by broad application of satellite communications systems and networks given in the area with huge territories and utterly uneven population distribution. The present state of a number of branches of the country economy is connected inseparably with the state of communication satellites. The satellites allow arranging high-quality, rapid and effective audio and TV broadcasting, communications and data transfer, Internet access, etc. The satellites are particularly effective solving the problem of communications in hard to access regions and areas with severe climatic conditions, like the Caucuses, Siberia and Far East. The advantages of satellite systems are beyond doubt when the communication networks are to be quickly deployed. The role of satellite communications and broadcasting grows substantially at the present time when it is necessary to switch over to digital TV and audio broadcasting. The only acceptable and at the same time feasible way of digital broadcasting coverage over the entire RF territory (both TV and audio broadcasting) is the satellite broadcasting, both distributive and direct (DSB).

During the decade Russia launched 17 communication satellites for civil purposes, out of which 11 space vehicles were fulfilling their target mission in early 2011. Only three satellites «Ekpress-AM33», «Ekpress-AM44» and «Gonets-M» No. 2 out of 17 satellites launched during this period were fully operational and served their target missions without limitations. The satellites «Ekpress-AM22», «Ekpress-MD1», «Yamal-200» and «Yamal-201» have faults in certain onboard systems and units which do not affect their target functions. The satellite «Ekpress-AM11» was lost in the orbit. The satellites “Ekran-M” No. 18, “Gonets-D1” No. 10, No. 11 and No.12 ceased their existence in the orbit after their service life expired. The satellite «Ekpress-AM2» fulfils its target mission only for 10 hours a day due to the failure of the solar panel orienting system. The orbital position correction system of the space vehicle «Ekpress-AM1» failed. The satellite «Ekpress-A1P» experiences unrecoverable faults and operates with significant limitations. In addition, «Bonum-1» space vehicle (built by Boeing and launched in 1998) successfully supports the satellite constellation for communications and broadcasting. The satellite «Ekspress-A3» continues its functions with severe limitations (built by Reshetnev Space Vehicle facility and launched in 2000). The modern satellite «Ekpress-AM4» was lost during injection into the orbit.

The civil communications satellite system reduced by five satellites versus its 2000 state. Russia with its unique space technology has become almost incapable to develop radiotechnical satellite components due to the grave crisis of the last two decades. It resulted in the fact that the on-board transponder of the national civil communication satellites of the last decade has been manufactured abroad, except Gonets type space vehicles based on 80s' technology. Poor quality and insufficient platform power do not allow Russia to realize its full orbital and frequency allotment.

The resources of the Russian satellite constellation are insufficient even to develop the existing VSAT networks failing fully satisfy the Russian market demand. The national satellites fail to provide enough power for radio links. The Кu-band transponders with the power 52…53 dBW would permit to use the arrays of 76…90 cm in diameter making the service to subscribers cheaper, and gain more potential users of services and means of fixed satellite communications.

The operating geostationary satellites are inaccessible for potential users in the vast subpolar regions of Russia. To solve the problem of telecommunications in the subpolar regions, there is a need for communication satellites in the high elliptic orbits to be included in future orbital constellation.

Before 2015 it is projected to set in operation the stationary communications satellites of the new generation with improved characteristics, orbital active life over 15 years, the onboard radio equipment power characteristics providing the subscribers with full range of modern telecommunication services using the VSAT stations with arrays less than 90 cm in diameter (the space vehicles «Ekpress-AM5…8», «Ekpress-AMУ», «Yamal-GK»). These satellites have more than double channel capacity than satellites of preceding «Ekpress-AM» series.

The implementation of the full-scale deployment of communications and broadcasting satellites in the Ка-band over the territory of Russia will be possible only after the launch of space vehicles Ekpress-AM5 and Ekpress-AM6. These satellites will carry up to 12 Ка-band transponders and maintain the service area with 10 narrow beams of multibeam arrays covering the western and eastern RF territories respectively. These transponders will provide a high energetic potential and enable the deployment of low-power VSAT-stations for subscribers of satellite networks.

The communications satellites, starting with «Ekpress-AM5», are based on the most powerful domestically designed Ekpress-2000 platform from the JCS "ISS".

While the Russian fixed satellite communications and direct telebroadcasting satellite constellations are developing more or less stably due to cooperation of the market operator – state-owned Russian Satellite Communication Company (RSCC) with enterprises and organizations of the space industry; the situation with two other areas of space communications, such as personal satellite communications and data relaying looks much more complicated.

The multifunctional personal “Gonets” satellite communication system is intended to transmit data and provide communication services for the subscribers in any point of the globe. According to the Federal program of Russia for 2006-2015, the “Gonets-D1M” system should include 18 “Gonets-M” space vehicles, 5-7 regional stations and provide data transmission for 200,000 subscribers. It was projected to launch six “Gonets-M” space satellites in 2009-2010 and afterwards to bring the orbiting satellite group up to 18 satellites by 2015. However, the satellites’ launches were delayed. Only one satellite “Gonets-M 2” was launched in 2010 instead of the scheduled three. The Roscosmos decided to postpone the “Gonets-DD1M” system until 2015. Thus, the model of cooperation between enterprises and organizations of the space industry without an independent target space system operator in fact yielded in a market failure. Though the first low-flying satellite for personal communications was created in the USSR in the mid 60s of the 20th century, the civil low-orbit system of Gonets communications satellites still does not exist after 20 years of development.

Currently the lack of spacecrafts for broadcast relaying strongly impairs the performance of the Russian segment of the International Space Station and remote Earth probing spacecrafts, inhibits the implementation of resource-saving and effective technologies of spacecrafts control and monitoring and other rocket-and-space engineering objects. The first “Luch-5A” MSRS satellite was projected to be launched in early 2006. However it was postponed repeatedly and finally was launched in December 2011. No low-orbit satellites projected for the next five or seven years, except the ISS, will have a communication system using the relaying satellite, thus it will be necessary to re-profile the projected MSRS, comprising three satellites «Luch-5A», «Luch-5Б» and «Luch-4» injected into the geostationary orbit, to the new objectives, part of which are being successfully fulfilled by the RSCC spacecrafts.

“Arktika” system is considered now as a promising multifunctional space system comprising “Arktika-MS” space communications subsystem with six satellites at high elliptical orbit (HEO).

The HEO communication systems have indisputable advantages over the GSO communications systems if the satellite is to send signals to high latitude (beyond 78º of the northern or southern latitude) locations, where it is hard or even impossible to receive the signal from the geostationary satellite. The deployment of expensive HEO or Tundra orbit satellites can be justified only by the need to solve the problems related with national security aspects.

In general, it can be concluded that the time has demonstrated the effectiveness of the market model envisaging cooperation between the satellite operator independent from rocket-and-space industry and spacecrafts manufacturers. This model is preferable to expand onto other space marketable projects.

Remote Earth probing

The remote Earth probing (REP) has been stably and dynamically developing during the last decade being one of the main space activities contributing considerably to the economy of developed countries. The space information has become the important source for solving the practical tasks of state and local administration. The data from the REP satellites serve to explore and use rationally natural resources, monitoring and elimination of the aftermath of natural disasters and man-caused emergencies, meteorology, climatology, urban, forest and rural economies; mapping; geology, geophysics, geochemistry, oceanology, and other earth sciences. The space information has both penetrated and intensively changed the everyday human life on the planet.

The qualitative changes in the equipment of satellites and space data processing technology have led to rapid growth in number of satellites orbiting and to development of national and regional REP programs. The American satellites with high resolution optoelectronic systems (up to 0.4 m) operate on the orbit successfully like those of the new WorldView-1 and GeoEye-1 generation. GeoEye Company began to develop the third generation GeoEye-2 satellite fitted with the high resolution (up to 0.25 m) optoelectronic equipment. During the last decade, the satellites were launched into the orbit fitted with the radars having the synthesized aperture of high and extra high resolution COSMO-SkyMed-1,-2,-3,-4 (Italy), TerraSAR-X and TanDEM-X (Germany), RADARSAT-2 (Canada) and RISAT-2 (India), ALOS (Japan). The RapidEye system (Germany) has been developed and operates successfully with its five minisatellites for monitoring natural and industrial disasters.

The global and Russian market of the space remote earth probing (REP) data is currently at the stage of emerging and is growing with the rapid rate of about 15-25 % per year. The share of internal Russian market amounts potentially to 10-15 % of the global market. At present the domestic REP satellites Resurs-DK1, Meteor-M No.1 and Elektro-L No.1 are in operation.

The “Resurs-DK1” has been operating since 2006. Under the Federal Space Program, the improved “Resurs-P No. 1” spacecraft is being developed in Russia; it is projected to be launched in the second quarter of 2012. The “Resurs-P” space system will comprise two similar spacecrafts. In addition, the “Kanopus-V” space system is being developed with two satellites to monitor industrial and natural disaster based on the broad use of engineering solutions from British SSTL Company (merged with EADS Astrium currently).

There are also two Russian meteosatellites on the orbit: “Meteor-M” No. 1 launched into sun-synchronous orbit on 17.09.2009 and “Elektro-L” No. 1 launched into the geostationary orbit on 20.01.2011. The remote earth probing data reception and processing facilities have been developed at Roscosmos (the research earth rapid monitoring centre) and at RosGidroMet.

It is noteworthy that the single Russian REP Resurs-DK1 satellite had been developed since 1996 and launched only in 2006 ten years after its designing began. This Russian satellite with the high resolution (1 m) optoelectronic system transmits the space data in the real time via the radio channel with the rate up to 300 Mbits. Note that the satellite operates with severe limitations due to the failure of a number of onboard systems. Besides, by the number of operating remote earth probing satellites Russia lags behind the USA (21 satellites), China (15 satellites), Germany (12 satellites), India (11 satellites), France, Canada, Japan, UK, Italy, Israel, and a number of other countries.

The development and operation of radar satellites are monopolized by the USA, Japan, China, Germany, France, Canada, Italy, India, Israel, and Korea. As regards the operating radar space complexes, Russia lags behind the international community and lost the USSR experience in this sphere. The domestic projects of radar observation satellites are off the state budget, and, since the REP market does not appeal the business structures, are in the deplorable embryonic state.

As a result of the prevailing situation, Russia does not have virtually any national REP space system. The operative space data received from foreign systems has low spatial resolution (less than 500 m) and does not permit any exhaustive situation analysis. The satellites scheduled to be launched in 2010 to monitor emergencies, like "Kanopus-V" and REP spacecraft "Resurs-P" are postponed to 2011.

To exploit the remote earth probing trend it seems expedient to switch over to an independent market model of the demand for REP satellites by concerned agencies and to establish the enterprises as operators of marketable REP services. One should also notice that the redundant classification of the space data processing results have led to the full loss by Russia its market position which existed early in this century when foreigners addressed us for photographs and mapping data collected by the Kometa-type satellites. The prevailing situation compels to believe that Russian industries will manage to overcome the lag in the development of REP systems only by borrowing the relevant technology and training the specialists at European and American companies. The possible alternative is to import the REP satellites directly; it will, in its turn, dictate the final loss of relevant competencies; substantial segment of high tech industries, like the national radio electronic industry, will be ruined in Russia.

Satellite navigation

As a result of implementation of the Federal target program "Global navigation system", the GLONASS system in Russia is providing the global continuous earth surface navigation from the altitudes up to 2,000 km. It has the characteristics (accuracy, accessibility, functionality) comparable with the foreign counterparts (GPS) at the present time. From 2006 to 2011, the GLONASS navigation field expanded over the territory of the Russian Federation from 72 % to 100 %, globally from 58% to 99, 4 %. After four GLONASS-M satellites were launched in November of 2011, the full set of orbital GLONASS satellites was established (24 satellites in three orbital planes). It is projected to allocate RUR 330.5 B in 2012-2020 to maintain and develop the satellite system.

The main problems with the national satellite navigation system are due to the needs to integrate the space system originally developed for national defence into the country economy and identify its ecological niche considering the concurrently operating American GPS system producing high quality signals, along with future European Galileo system, Chinese and, likely, Indian systems. The adoption by the national market the capabilities of the satellite navigation and use of Russian GLONASS system as a global competitive advantage for the high-tech businesses is one of the key tasks for national institutes of development.

Basic space research

Due to the apparent reasons of budget limitations, the development of national space research using own space means has stayed the least state financing priority throughout years. 12 satellites were launched to serve research during 2001-2010. Several smaller satellites and university satellites failed to reach the orbit or were not activated due to the accidents with launch vehicles. The technological research satellite “Foton-M 11” was lost while injecting into the orbit. Only three satellites “Koronas-F”, “Foton-M 2” and “Foton-M 3” fully operated throughout their life time.

The “Koronas-Foton” satellite was launched in 2009 to monitor the sun from the earth orbit. A considerable scope of scientific data was gathered during the mission. However, the satellite failed in less than one year after its launch due to the power supply system maloperation. Thus, the development of modern long-living satellites for space research is a grave problem for the Russian rocket-and-space industry. It was a formidable success when in July 2011 the astrophysical research observatory “Spektr-R” was finally launched after 20 years of development and it is beginning its actual research mission on the orbit now. But four months later, interplanetary “Fobos-Grunt” station, also designed by NPO Lavochkin, failed to start from the earth referenced orbit, virtually putting the end to the Russian interplanetary research program revival after twenty year long pause. Thus, the development of complex unique non-standard multitask interplanetary spacecrafts is becoming an apparent problem for the Russian industry. The present-day approaches to programming of basic space research should be revised radically.

At the same time, one should note that use of relatively simple “Foton-M” spacecrafts based on a single-use recoverable capsule that has been tested in outer space for many times made it possible to obtain a range of results in the field of microgravity research, including discovery of new effects in physics of liquid, phase transitions and condensed matter physics, new biophysical and biochemical phenomena in biological objects affected by space flight factors, measured data of physicochemical parameters of the processes, occurring in liquid phase, during phase transitions and in multiphase systems for compilation of reference tables used in the industry. We have received reference samples of materials for electronics, alloys and composites, producing strains of microorganisms for tackling environmental challenges and producing animal feed, as well as 3D tissue and chondral structures for application in clinical medical practice. Applied projects in the field of microgravity are among promising areas of commercialization of the space research.

While Russia lacks any opportunity to launch domestic interplanetary mission, the scientists of the Russian Academy of Sciences and Russian universities take part in international research projects to the extent of separate experiments made and units installed on board of the foreign space vehicles. Thus, Mars Express, a space vehicle of the European Space Agency which operates in Mars orbit from 2003 is equipped with Russian instruments SPICAM-M, OMEGA-M AND PFS-M. Venus Express, another mission of the European Space Agency, operating in Venus orbit from 2005, makes experiments using Russian-made instruments SPICAM-V, OMEGA-V, and PFS-V. Mars Odyssey, a NASA mission, operates in Mars orbit from 2001and makes experiments with the Russian-made “HAND” equipment. NASA’s Lunar Reconnaissance Orbiter makes experiments using LEND, a Russian-made Lunar exploration neutron detector. Launched on November 26, Mars Science Laboratory/Curiosity also contains DAN, a detector provided by the Russian Federal Space Agency.

New players (China, India, Japan and the European Union) caused an essential revival of activity in outer space exploration during the last decade. Their projects and the current science research load are amazing in their grandiose scale. The scope of permanent research covers the near-Earth space environment, the solar system, the planets and astrophysical processes. Moon flights became the focus of space research in the last and coming decades. The Mars program is also essential to space activity. We hope that Russian interplanetary missions and observatories will find their unique way into international research cooperation.

Manned Space Flights

Today's manned space activity program of Russia is connected with the extension and operation of the International Space Station (ISS) and with a complex of research and applied activities conducted at the station. The ISS has been operating in the Earth orbit since November 1998. The station has been manned since October 2000. Today the ISS comprises 14 main modules, including 5 Russian modules.

According to Russian orbital segment development program, in 2013 a multifunctional laboratory module (MLM) will be added, and in 2014 a node module (NM) will be included that will make it possible to dock up to four additional modules to the Russian ISS segment. Further on, two scientific and research modules (SRM) are expected to be docked to NM in 2015-2016.

Since May 29, 2009, a crew of six members, including 3 Russian ones, has been working at the station. Transportation and technical support is provided by Russian spacecrafts Soyuz TMA and Progress M, European transport spacecraft ATV and Japanese transport spacecraft HTV.

Long ISS operation has demonstrated a high level of reliability and flexibility of the architectural and technical solutions used, as well as existence of certain organizational and technical problems. Delays in construction of the ISS (in particular, of its Russian segment) considerably reduced the duration and field of its target use. Although the station is automated to the greatest extent possible, almost permanent presence of the crew is still necessary, which is a disadvantage of construction and design solutions used. The station is not comfortable enough for its crew: although it has large pressurized compartments, most of them are used for placement of service systems and equipment delivered to the station. A safe manner of performance of certain important experiments at the ISS is problematic or even impossible.

Nevertheless, some important results were obtained during implementation of the Long-Term Program for Scientific and Applied Research and Experiments in the Russian ISS Segment. By the end of 2010, 38 experiments were completed, while 55 experiments were at the stage of mission implementation and 79 more experiments were at the stage of ground preparation.

The results of space experiments gave birth to such designs as "Regent" therapeutic suit – an axial loading suit for non-pharmaceutical treatment of neurological patients, "Cardiosleep-3" complex used for evaluation of the functional state of the body during the night-time sleep by contactless recording of physiological functions, "Cardiovisor" heart screening computer system. A new biotechnical medication, based on highly-efficient NZh-13 strain, was developed – plant growth hormone Micefit. Practical results have been obtained during development of oil biodegradation agents, isolation of clones for an investigational batch of hepatitis B vaccine that complies with all quality parameters and is highly active.

The completed stage of "Crystallizer" Experiment that was aimed at studying the structure of insulin crystals, grown at the Russian ISS segment, provided results that make it possible to launch in Russia manufacturing of a genetically engineered insulin product to be used for treatment of severe diabetes.

The studies conducted within the “Plasma Crystal” Experiment revealed a number of totally new effects in plasma with strongly charged macroparticles.

Educational and popular science projects are among the most important objectives of the activities at the International Space Station. Such projects as Ten-Mayak (Shadow-Beacon), MAI-75, MATI-75 and others made it possible to engage schoolchildren and students from Russia and all over the world into space experiments.

Notwithstanding all the diversity of research and experiments conducted at the Russian ISS segment, the station’s efficiency in terms of important scientific and applied results is not high enough, which is connected with the problems of development of new Russian modules, limited resources and unsuitability of the ISS for certain scientific and applied studies (in the field of microgravity, energy, radiation, etc.). Implementing a program of commercially applied research at the ISS can become an important area of innovative activity.

Launch vehicles and cosmodromes

In spite of preserving competitiveness in the market, most of the Russian carrier rockets are outdated. Almost all currently used launch vehicles and cosmodromes were put into operation twenty or more years ago. Outdated components are used for building carrier rockets; and ground-based complexes have undergone numerous overhauls. In addition, light and heavy carrier rockets use toxic fuel components.

The Federal Space Program 2015 provides the development of a system of launch vehicles based on such carrier rockets as Proton-M, Russ, Angara, etc. The top priority area of activity is completing the development and tests performance of Soyuz-2 space carrier rocket with Fregat upper-stage rocket at “Plesetsk” Cosmodrome. It is expected that starting from 2013 Angara carrier rockets will be required for launching prospective spacecrafts under federal programs from Plesetsk Cosmodrome. The available time reserve is enough to complete the development of Angara rocket and test it to a level that will exclude any technical risk for the program to be shifted to another carrier rocket.

Design activities have started to create a unified transport module that will use a solar electric propulsion unit and a nuclear power propulsion unit. Flight tests are expected to start after 2015. Technical proposals have been elaborated to develop a reusable first-stage space rocket system MRKS-1. It is expected that the results of the contest of design concepts will be announced in 2012.

Today, Baikonur Cosmodrome still remains Russia’s main cosmodrome used for manned launches and placing of spacecrafts in a geostationary orbit. Work for building of a new Russian cosmodrome was started in April 2007 at a meeting under the supervision of the President of the Russian Federation regarding the issue “On long-term support of the space activity of the Russian Federation”.

According to the performed analysis of the condition of different regions and in accordance with the Far Eastern Federal District Development Program, a decision was taken to create Russia's new cosmodrome for scientific and socioeconomic launches in the Svobodny District, Amur Region. As a result, on November 6, 2007 the President of the Russian Federation signed the Order *On the Vostochny Cosmodrome* which gave a start to the development of a new cosmodrome in Russia.

The top-priority task within the construction of the new cosmodrome is to create an industrial base, without which it will be difficult to build the required ground-based space infrastructure in the Far East in due time. Commercialization of a range of services provided at the cosmodrome and development of public-private partnership during cosmodrome construction and operation are among the promising directions for the mid-term development of innovation business in the field of space activities.

The new cosmodrome will enable Russia to implement its space policy, launch manned spacecrafts and space vehicles operating in a geostationary orbit from its own territory.

Presidential projects

The fact that on June 18, 2009 at the first session of the Presidential Commission on modernization and technological development of Russia's economy, space technology was attributed to the number of priority directions of technological breakthrough, became a confirmation of significance of the Russian cosmonautics in innovation development of the country. The president of the Russian Federation approved five projects on "Space and telecommunication" on November 19, 2009. They include:

Development of GLONASS services market. "ERA GLONASS" emergency response system development based on multi-functional receiving devices, manufactured in Russia.
The project is implemented by OJSC "Navigation information systems" within the framework of 2013 commissioning "ERA GLONASS" emergency response system based on multi-functional receiving devices, manufactured in Russia.

Vehicle location systems development.
This project is being realized by OJSC "Russian space systems" within the framework of introduction the vehicle location system (complex) into service in 2014 and mass production of personal radio buoys for COSPAS/SARSAT searching and rescue system. The project is intended for navigation safety and effective management of marine and river transport in the Russian Federation, establishing Russian national space segment of Automatic Identification System (AIS), as well as further development of the searching and rescue system for radio buoy users within the territory of the Russian Federation, provision of operator services on above-water situation reporting for various consumers in international market as well.

Establishment of intelligent systems for monitoring and control of condition of technically complicated objects. This project is being realized by OJSC "NII of physical measurements" within the framework of test operation in 2013 of intelligent monitoring systems and systems for non-destructive inspection of the condition of technically complicated objects for their safe operation.

Establishment of full technological cycle for manufacturing a new generation of solar panels. The project is being realized by OJSC "Research Production Enterprise "KVANT" within the framework of the beginning the mass production in Russia of a new generation of solar panels in full technological cycle in 2012 . The project aims to achieve at least 15 year long lifetime for all types of spacecrafts and to increase spacecraft power loading more than twofold.

Development of a transporting and energy module based on megawatt-class nuclear power propulsion system. The project is being realized by Federal State Unitary Enterprise "Keldysh Research Center" together with organizations of the State Corporation "RosAtom" within the framework of development of a transporting and energy module based on nuclear power propulsion system for flight development tests in 2018.

“Presidential projects” is a field for collaboration in a format of public-private partnership, common R&D Centres establishment, commercialization of their results, etc.

Global markets and international collaboration

Russia, having a well-developed space potential and being a leader in provision of launching services in manned space exploration, in the field of navigation, collaborated with foreign countries, including commercial basis, in all general directions of space activity.

Today, Russian carrier rockets constitute 40% of the whole global scope of launchings. Achievements of Russia in this field have been widely used by realization of such commercial projects as “Sea launch”, “Earth launch”, “Soyuz in Centre Spatial Gayanais”.

The project “Soyuz in Centre Spatial Gayanais”, implemented by Russia, European Space Agency and France, is not only a mutually beneficial project of joint use of the carrier rocket “SOYUZ-ST” in the global space market of launching services, but a ground for a long-term collaboration of Russia and Europe in the field of development of prospective carrier rockets as well. The first launch of the Russian carrier rocket from the space launching site in French Guiana took place in October 21, 2011.

The projects “Sea launch” and “Earth launch”, where Russia and Ukraine are the key participants, ensure efficient commercial use of the Ukrainian carrier rockets from “Zenit” and “Dnepr” families.

Within the framework of the international commercial program of space tourism on “Soyuz” spacecrafts at the International Space Station in 2006-2010, 4 participants from the USA and Canada performed the flight and one of them – twice.

Accumulated experience of development and long-term operation of manned space complexes allows starting joint works on development of manned means for human expansion beyond the boundaries of circumterrestrial space, as well as for lunar and Martian missions. Since November 2008, there has been carried out a realization of the international project “Mars-500” on imitation of the manned flight to Mars in Russia. Three representatives from Russia and by one from France, Italy and China participate in this experiment. This project became the first step in preparation of the manned mission to Mars, implementation of which is possible only in strong international cooperation.

In 2006-2010 the work on complex participation of the Russian organizations in research projects within the framework of the 7th Framework program of the EC was being actively held. In 2011 a National contact point on basic and applied research in the field of outer space was created.

Collaboration between industrial organizations of Russia and foreign countries is being activated. Mutually beneficial joint projects have been implemented in the field of satellite communication. In 2008-2009 three spacecrafts for communications and television broadcasting (“Express AM-33”,”Express AM-44”, Express MD-1”), made by the Russian manufacturers in active interaction with the leading aerospace companies of Europe and Canada, were launched in Russia.

Russian enterprises also collaborated with a number of countries, actively developing their national space programs, by providing support in development of launch vehicles and other elements of space infrastructure.

Opportunities and achievements of the Russian launch vehicles in global market should not be shadowed by the fact, that a real danger today is a gradual exclusion of carrier rockets from the global market due to introduction of carrier rockets of a new generation, developed on fully commercial approaches, as well as by the return of Chinese carrier rockets into the space segment.

Current state of the Russian space activity, directly determining the opportunities for commercialization of the corresponding technologies and development of innovative eco-

environment in the sphere of ST&C Cluster responsibility, is characterized by a number of system-wide problems.
The number of failures in rocket and space technology increased. The failures in communication, navigation, and meteorology spacecrafts are caused mostly by manufacturing defects. For monitoring spacecrafts the design faults are the major problem.
Year by year the efficiency of the activity in realization of FSP is being reduced by the boost of funding from 27% in FKP-200 up to 100% in FKP-2015. Moreover, a substantial priority in ISS-project funding over the other scientific projects can be noticed.
Analysis of the space activity funding results shows that the total funding of civil space programs in Russia in 2010 became past RUR100 B for the first time. During the first decade of the 21st century, the civil space activity funding was over 13 billion dollars and increased 11, 5 times as much in roubles and 11 times as much in dollars. However, during those years the real orbital group of Russia did not increase, according to the experts, and it reduced by almost 30 satellites, including 24 civil satellites. If in 2001 it had 107 spacecrafts, including 48 civil satellites, then at the end of 2010, it had not more than 78 satellites, and 24 of them were the civil ones. An actual double decrease of the number of civil spacecrafts happened during the last ten years.
Russia also lags in the output value per employee in comparison with the USA and EU. Excessive production capacities increase costs of labour and material resources and cost of rocket-and-space equipment. With the growth of modernization in rocket-and-space industry the labour intensity of production of rocket-and-space equipment and the number of rocket-and-space industry employees are not being decreased.
According to the investigation of the Ministry of Economic Development of Russia (March 2008), labour productivity in space industry in Russia is far behind the leading countries of the world. According to the of Ministry data , in the rocket-and-space industry of the country output value per employee equals 14.8 thousand dollars annually, whereas, in the EU this indicator equals to 126.8 thousand dollars, i.e. it is 8 times higher than in Russia, and in the USA - 493.5 thousand dollars, that is 33.3 times higher.

Specified reasons together with the absence of Russian-made electronic component base, lack of priority development of onboard instruments, critical lag from the global level in major target and production technologies, poorly regulated pricing, undeveloped legal base and decrease in efficiency of the active reliability assurance system have lead to non-fulfilment of the Federal space program. Only during the period from 2006 until the present time, 18 launches of provided by the FSP-2015 spacecrafts did not take place. Substantial lag is noticed in the programs of development of spacecrafts for basic research, there is no good vision of directions for concentration of efforts and resources.

This situation, as a whole, is characterized by the growing lag in quantity and quality levels of Russian space vehicles that are currently in use and development.

Manufacturing, scientific and technical potential of the rocket-and-space industry, which was created in the USSR for large scale production of spacecrafts for various designations, needs a serious restructuring, aimed at overcoming growing technological and scientific lag of Russia in this sphere and return to the currently lost positions.

Along with the obvious problems of development and operation of spacecrafts, it is necessary to mention a number of institutional system problems that precondition the present state of the Russian cosmonautics. These problems include:

In the field of target setting, program and goal-oriented planning, institutional development and public support of space activity:

- Lack of harmonized system of state target setting on strategic issues of the space activity development;
- Closed informational nature of political, programming and planning principles of the space activity, immaturity of mechanisms for public discussion and independent examination;
- Preserving uncertainty in distribution of roles “Customer- Contractor” in the system of planning and management of the national space activity, lack of strategic vision of institutional transformation of the space agency role in conditions of growing independence of space services consumers;
- Lack of large and medium non-state businesses in the sphere of development and target operation of spacecrafts;
- Bulky, fragmented, user-unfriendly system of storage and access to scientific and technical documentation and historical information.

In the field of ground space infrastructure:

- Lack of national network of ground stations, compatible with international communication frequencies and standards.

In the field of organization of application of results of space activity in the economy:

- Lack of full-grown operators of space services, providing consumers services on corresponding markets, first of all – in the field of remote Earth probing.

In the field of functional space technologies

- Long terms of production of separate onboard systems and spacecrafts as a whole;
- Lack of the advance development of the instrument and sensor base for the prospective spacecrafts, subordinate role of the developers of the key target-oriented onboard equipment in the structure of cooperation in the space complexes development.
- Prolongation of transition to new unified space platforms.
- Threatening state of national electronic component base, absence of stable import of electronic components.

In the legal field

- Undeveloped legal base for investments and development of entrepreneurship in the field of the space activity.

In the field of rocket-and-space industry and production technologies

- Continuing uncertainty in the part of sectorial competition and reservation of production capacities and design schools;
- Enclave character of the rocket-and-space industry, absence of diversification and synergetic effect with the adjacent sectors of the industry;

- Actual freezing of the investment process on reproduction (re-equipment) of the active operating key assets at the most part of enterprises of the rocket-and-space industry in the period of 1992-2003;
- Lag of technological capacities, low level of capital productivity and labour productivity that precondition the necessity of a wide-scale transfer of complex production technologies from abroad.
- Absence of good sectoral information system, directed at monitoring and support of decision making on state programs in the field of the space activity;
- Insufficient number of highly qualified specialists, high average age of employees, undeveloped system of staff training at all levels, insufficient social support of the specialists.

Staff problems of the industry should be considered more thoroughly. Rocket-and-space industry of Russia, like other high-tech industries of the national economy, was damaged during the change of state authorities in 1991. In the 90s funding of civil space programs was decreased by factor of 12. Thus, in 1992-1999, space industry lost its 20 to 40 year old personnel, which caused an immediate negative effect on the industry.
In connection to this, now the primary problem of the industry is how to refill the generation of Soviet scientists (average age about 60 years), engineers and qualified employees (average age is over 50) who form the foundation of the Russian rocket-and-space industry personnel. Unfortunately, this problem has become of all-Russia scale and relates not only to the space industry, but to the system of training of employees, technical, engineering and scientific staff. This is the reason why qualified specialists of the rocket-and-space industry are nowhere to search for.
The analysis shows that if during the next 5-7 year Russia cannot overcome the lag in the space industry not even from the obvious leaders (USA and united Europe), but at least from successful players of the second level, first of all – India and China, then it will not be able to do it ever.

To do this, it is necessary to recover staff potential of the industry, to perform its deep modernization, which cannot be done without global experience. Otherwise, even large financial investments will not give a proper and expected effect, which can be observed during the last years.

Along with the mentioned problems, which shall be settled immediately through measures, determined by the common vector of space activity development and state industrial policies in the field of space activity, it is necessary to mention a number of positive factors in the state of Russian cosmonautics. They include:
- Unique geographical location, geopolitical status and distribution of productive powers and resources within the country territory , which in a number of cases objectively determine competitiveness of space info-communicational solutions in comparison to non-space ones;
- Availability of a number of competitive productions in the field of rocket-engineering, production of special materials, systems and components for the manned spacecrafts and long-term orbital stations;

- Availability of certain viable business solutions enabling prospective development of a new working system of relations in the sphere of space services providing based on intersectoral cooperation. First of all, this is the present system of relations in the field of fixed satellite communications.
- Preserved till the present days system for training of highly qualified specialists for the space industry;
- Accumulated experience of constructive cooperation with various Western centres of competencies in the field of high technology, under the conditions of real multi-polarity that allows to count on the transfer of manufacturing and functional technology;
- Significant reserve of non-material factor, which is called “goodwill” in economics – a positive image, “positive reserve”, accumulated by cosmonautics in the social consciousness in Russia and abroad.

What is the place of Skolkovo Foundation and its Space Technology and Communications Cluster in this situation? In response to the challenge, thrown out by the Soviet Union’s launch of the first artificial satellite of the Earth in 1957, the USA established DARPA (Defence Advanced Research Project Agency), intended for detection and development of the most important high technologies and projects, allowing to ensure the leading positions of the country in technological and innovation domains. Large-scale reforms of school education, directed at training of youth for a new reality and new technological life, were started. To our view, in the modern Russian reality, ST&T Cluster can perform, to some extent, the functions of “our Russian DARPA” in systematization and consolidation of breakthrough technology and recreation of product chains in the sphere of space activity on the basis of approaches, relevant for the mixed modern economy. Besides, we consider that the use of opportunities and competencies of the Cluster for establishment of a “school of the future”, where achievements and opportunities of cosmonautics shall become one of the core foundations for education in the field of natural sciences and world outlook – from secondary school to post-graduate advanced training programs.

II. TARGETS

Based on the object statues and mission of the Skolkovo Fund, the ST&T Cluster has defined its operation targets as following:

- **Search for, attract and select potential subjects of innovative process, facilitate their cooperation and provide the environment for full cycle innovation process establishment in part of technology for the development and target use of spacecrafts (upstream technologies), and finally establish multilevel business environment in the field of space activity**
- **Internal and external competences of Russian companies' development to increase their performance on space products and services markets**
- **Spin-off processes assistance in commercialization of the specialized manufacturers' potential to launch products and services with clear commercialization prospects on horizontal markets**
- **Assistance in filling critical gaps in product chains for space products and services vertical markets**
- **Establishing information-communicative and educational environment in order to facilitate the human capital assets development and adaptation of rocket and space and allied industrial sectors to the requirements of modern market environment**
- **Development of legislative and regulatory foundation for business activity and public-private partnership in the field of space activity**

III. ST&T CLUSTER PRIORITY SYSTEM

In order to achieve the targets ST&T Cluster has designed and supports a three level priority system.

A. Within the framework of ST&T Cluster subject index through routinely resuming expert procedure are determined **ST&T CLUSTER GENERAL PRIORITIES** which principally provide the selection and support of projects that are presented by applicants in an initiative order, and reflect the Cluster's experts view at the profile technology development prospects in order to achieve the targets of the Skolkovo Fund. Russian Foundation for Basic research initiative tenders could serve as an analogy. In version 1.0 of the present document the General Priorities are defined by expert review. They include Group V priorities, determined according to the modes of space activity

B. If appropriate the **ST&T CLUSTER SPECIAL PRIORITIES** are determined that reflect the Cluster contribution to dealing with nationwide problems of technological development, primarily in vertical markets development. RFBR oriented tenders "ofi-c" could serve as an analogy. Special priorities are determined and actualized as it is necessary in the ongoing process of communication with ministries, agencies, development institutes, foreign partners In version 1.0 of the present document the Special Priorities are defined as following:

1. Priority directions supported by the Skolkovo Fund on behalf of Roscosmos (Rk Group);
2. Middle- and long-term complex priority directions (Ko Group)

V. The third priorities component is – **ST&T CLUSTER PROACTIVE PRIORITIES** reflecting subject directions and work formats that Cluster considers as useful and specially performs active self-directed activities in order to attract the participants and establish innovative forms of cooperation (collaborative centers, SkolkovoTec departments, Web solutions etc.). RFBR oriented tenders "ofi-c" also could serve as an analogy. In version 1.0 of the present document the Proactive Priorities are defined as following:

1. Priority basic and exploratory research (Pro Group)
2. Projects on innovative ecosystem establishing (In Group)
3. Projects on aerospace technology development (A Group)

IV. ST&T CLUSTER GENERAL PRIORITIES

Index and Procedure

The experts determine ST&T Cluster General priorities with reference to Cluster's subject matrix. For every broad type of space activity the subject matrix determines several target markets and directions for provision of effective space activity, after that specific technological priorities and viable formats are determined for every "activity type - target market" pair for implementation within Skolkovo Project. The subject matrix is biuniquely tied to the index which is used for identification of Cluster expert competencies and applicants projects directionality.

Space activity types list

V1. Space communications and broadcasting
V2. Earth remote sensing and hydrometeorology
V3. Space navigation
V4. Industrial space manufacturing
V5. Space exploration
V6. Basic space research
V7. Space activity on behalf of the Defense and national security (not considered herein)
V8. Launch vehicles (LV) , LV subsystems and components
V9. Spacecraft unified platforms and technology
V10. Launch complexes and other elements of cosmodrome ground infrastructure
V11. Manufacturing facilities, bench и test equipment
V12. Ground control complex
V13. Software and data support in the field of the space activity

List of Target markets and directions for provision of space activity efficiency

P1. Mass (horizontal) market for products and services targeted at the end customers, small and medium businesses in Russia and abroad (B2C, B2B)
P2. Corporate (vertical) market for products and services targeted at large corporations and government customers in Russia and abroad (B2B, B2G)
P3. Vertical market for products and services targeted exclusively at government customer (national security, basic science related products and services) (B2G)
P4. Support for basic and applied research and all stages of education
P5. Developing institutional environment for innovations

List of the Skolkovo Fund activity types (formats)

C1. Establishing R&D centers within large space oriented companies
C2. Skolkovo Centre participants attraction
C3. Skolkovo Centre projects support;
C4. Establishing space oriented shared testing centers, preproduction facilities and prototyping centers;
C5. R&D results marketing and commercialization
C6. Skolkovo University for innovative technology (SkolkovoTech) establishment and development

C7. Establishing Skolkovo Centre sci-tech library

At the present development stage of the Cluster priorities in the main directions of space activity, the priority technologies were determined, however, without reference to target markets and the Skolkovo Fund formats. Revised list of priorities, target markets and formats will be available upon development of the next version of the document in 2012 Q1.

General priority technologies in types of space activity

V1. Space communications and broadcasting

The section includes the list of most important directions of space communications and broadcasting development that are considered reasonable to implement within innovative R&D designs that are looking for the Skolkovo Fund support. Innovative ideas of particular interest are targeted on extending or/and establishing new market segments for satellite communications and broadcasting including the employment of new Q/V bands. Innovative projects of system nature for international cooperation could be of particular interest as well. Innovative propositions may be targeted at solving system problems, as well as at specific particular problems that are related with design and manufacturing of satellite communication and broadcasting key elements.

In accordance with the above, ST&T Cluster priority technologies include:

V1.1. Communications and broadcasting satellite systems based on superhigh bandwidth geostationary satellites to provide ground networks that enable the Internet access for individuals and small businesses.

V1.2. Communication satellite systems based on high bandwidth non-geostationary satellites to provide trunk and transport channels to benefit the development of 4G ground mobile networks.

V1.3. Satellite systems for direct and distributive TV and audio broadcasting based on geostationary satellites to provide subscriber networks with TV and audio programs

V1.4. Communication and broadcasting satellite systems based on geostationary satellites with on-board signal processing to provide custom topology space and ground communication networks, and special broadcasting and warning networks

V1.5. Communication and broadcasting satellite systems for experimental purposes in the new technology development in the field of communication and broadcasting, and new frequency ranges exploring.

V1.6. Onboard and ground equipment components for communication and broadcasting satellite systems including components for the new Q/V bands exploration

V2. EARTH REMOTE SENSING AND HYDROMETEOROLOGY

Earth remote sensing is a rapidly developing segment that now sees the second wave of its commercialization when new fundamental projects and solutions are based not only on public-private basis, but on completely for-profit principles. ERS is a cross-sectoral area: ERS tools are created by the space sector, ERS products are created by IT sector and used as the basis for decision making by many other sectors of economy. Innovative propositions of particular interest are targeted either at the build-up of new ERS market segments, or at the complementary addition of a new quality to the solutions that are present on the global market. The innovations may be targeted at system problems in the space and ground segment, specific technological problems in ERS system development, the development of ERS based applications for various sectors of the world economy.

In accordance with the above, ST&T Cluster priority technologies include:

V2.1. ERS space systems that create either new niche ERS products or services, or complementary ones to the existing international grouping having significant potential on the global commercial market, including optical, radar, infrared bands and hyper spectrometry solutions.

V2.2. Technology development for the space segment of ERS systems, satellite platforms and payload configurations.

V2.3. New generation round segment development. Technology complex for the space monitoring centers Data-acquisition and control station network development (X, S, K–bands).

V.2.4. Software development for ERS products processing, including first order, specialized, subject-oriented processing

V2.5. ERS based subject-oriented services development for various sectors of economy including agriculture and silviculture, disaster prevention, insurance market, cadastral registration in B2G and V2B segments.

V2.6. Public (B2C) services development based on ERS information using network technology (Internet, mobile communications).

V3. SATELLITE NAVIGATION

Modern navigation market is a fast growing, forming one that is defining new business models and its new leaders. Russian companies have a good chance to become new market leaders and large global companies. Today they have a competitive advantage based on GLONASS system. Navigation market resides at the cross of four high-tech global segments: IT, microelectronic, automotive and telecommunications. Each of these segments is in the process of rapid quality changes, and this fact defines highly innovative nature of the navigation market. It is the ongoing process of converging navigation, information and communication technologies, devices (smart phones, tablets, etc.) and services. As a result there is a single innovative technology segment (inc-technology) – information-navigation-communication segment. The inc-technology is one of the technological mode 6 development drivers.

In accordance with the above, ST&T Cluster priority technologies include:

V3.1. Design of system and technological solutions in part of navigation system space segment development

V3.2. Design of GLONASS/GPS multisystem navigation chipsets (with a prospect view of other satellite navigation system)

V3.3. Design and production setup of specialized equipment with navigation function meeting various «pedestrians» demands.

V3.4. Design and production setup of universal automotive navigation equipment providing a large list of services along with the capabilities for protection and searching, monitoring, satellite navigation based toll payment, work-rest regime compliance;

V3.5. Solution design for navigation-information systems providing services to the end customers, such as: transportation monitoring systems, smart transportation systems, toll payment systems based on satellite navigation, sectoral solutions, etc.;

V3.6. Design and provision of navigation-cum-information services for «pedestrians» and individual «motorists», including intuitive interfaces and monetization models;

V3.7. Equipment, solutions, services (including their monetization and provision models) design for different segments of highly professional navigation market.

V4. INDUSTRIAL SPACE MANUFACTURING

Industrial space manufacturing, understood as employing of space condition for new materials and substances manufacturing, is in the stage of its conceptualization now. A lead that Russian space sector gained during the time of space material research program, using among others specialized unmanned space vehicles, will allow domestic companies to contend for the leadership at the early development stages of appropriate markets.

In accordance with the above, ST&T Cluster priority technologies include:

V4.1. Individual experiments and experimental programs are to run on board of the support spacecrafts in order to improve ground manufacturing of the advanced materials (dielectric materials, semiconductor structures, alloys, solar battery photocells)

V4.2. Research of producing materials specifics using ultrahigh-temperature synthesis for repair procedures in space and possible improvement of different ground producing units

V4.3. Customized biopharmaceuticals production (e.g., biodegradants of oil and other products of petro-organic synthesis)

V4.4. Human cartilage production for on the ground implanting surgery, other materials for medical purposes

V4.5. Experimental programs in physics, chemistry and biology of gravity sensitive phenomena for academic and educational research organizations

V5. SPACE EXPLORATION

The section includes the list of most important directions of space exploration technology development that are considered reasonable to implement within innovative R&D designs that are looking for the Skolkovo Fund support. It should be noted that in vast majority manned space flights still remain in the government activity domain, accordingly, this direction of business projects should target the vertical markets. The only exception is the area of suborbital space flights that are at the moment very close to forming appropriate horizontal markets based primarily on the paradigm of space (extreme) tourism.

In accordance with the above, ST&T Cluster priority technologies include:

V5.1. Self-sufficient (independent) space systems – systems with advanced autonomy level in respect to the ground control complex

V5.2. Intellectual systems – systems with advanced computing capabilities and enhanced software, systems with AI elements

V5.3.Open architect systems – subsystems, systems and complexes designed according to the standards that allow to design, test, and upgrade the product using parallel design method with minimal costs

V5.4. Energy saving systems – systems with reduced subsystem energy consumption, low conductive and distributive losses, or having low per unit cost energy generation

V5.5. Integrated complexes – complexes that have different target purposes, and capabilities for integration via the system of standards, actions and facilities into a consolidated infrastructure

V5.6. Robotic systems – systems that use robotics controlled by intellectual systems or human

V5.7. Virtual space systems – systems for acquiring, processing and displaying multi-sensor information to the remote user to form the telepresence

V5.8. Outer space closed-cycle life-support systems

V5.9. Biotechnological materials and pharmacology targeted at an accelerated adaptation to the spaceflight conditions and further terrestrial readaptation

V5.10. Systems and methods of cosmonauts psychological adaptation, accelerated training and preparation with capabilities for further technology diversification for horizontal mass markets needs

V5.11. Spacecraft crew data support systems and facilities

V5.12. Spacecraft crew flight gear and support equipment with potential to further technology diversification for the horizontal mass markets

V5.13. Tools and means for medical monitoring, spaceflight factors protection, sanitary and hygiene facilities, and food supply.

V5.14. Systems, technology and complex business solutions in the field of suborbital space flights and space tourism

V6. BASIC SPACE RESEARCH

There are several areas of basic space research in the world nowadays. The research is performed with a wide variety of spacecrafts. They have different targets and various scientific equipment.

For more the 15 years domestic spacecrafts for solar and solar system research on behalf of basic science have almost been absent in the outer space, while the research has been actively advanced by foreign spacecrafts. Russian scientists continue the space research by installing Russian-made scientific equipment onboard ESA and NASA spacecrafts, as well as by participating in foreign space mission science support teams.

Therefore, the Cluster’s main objective is establishing wide international innovative structure for implementation of shared basic-science space experiments in cooperation with NASA and ESA, as well as developing world-class technological platforms for implementing a new class of space instruments, support systems and a new generation of electronic components having high radiation immunity for long-term space missions.

Within the framework of the Skolkovo Fund programs basic space research activities are supposed to be agreed and further implemented in cooperation with SkolkovoTech at the following stages of ST&T Cluster Priorities adjustments.

V7 (RESERVED)

V8. LAUNCH VEHICLES (LV) , LV SUBSYSTEMS AND COMPONENTS

The section includes the list of most important directions of LVs, boosters and their components technology development that are considered reasonable to implement within innovative R&D designs that are looking for the Skolkovo Fund support. Business project for this direction should be targeted at vertical markets and implemented primarily in form of LV oriented shared testing centers, pilot facilities and prototyping centers.

In accordance with the above, ST&T Cluster priority technologies include:

V8.1. Aerogas dynamics (aerodynamics and aerothermodynamics, hypersonic and supersonic combustion problems)

V8.2. Thermal control and heat protection;

V8.3. Materials and structures

V8.4. Main propulsion system and propellant-feed system

V8.5. Item control system, including diagnostics system

V8.6. Ground infrastructure, including inter-mission operations;

V8.7. Ecological (environmental) safety and flight paths

V8.8. Low cost transportation systems – low cost crews and cargo ferry systems, including:

Balloon aerospace systems

Aeroballistic recovery package

Space elevator

V9. SPACECRAFT UNIFIED PLATFORMS AND TECHNOLOGY

This section priorities could be implemented on government procurement vertical markets as well as in development of diversification projects on rocket and space technology transfer into various sectors of economy. In these directions could be involved virtually all formats of the Skolkovo Fund .

In accordance with the above, ST&T Cluster priority technologies include:

V9.1. Facilities and technology complex for assembling and commissioning of different application large space structures in a space flight environment

Concepts, methods and materials for space self deployable structures

Inflatable expandable structures for the manned spacecraft crew compartments

Facilities, methods, materials and design solutions for multihull manned spacecraft assembly in the spaceflight environment.

V9.2. Prospective space power plants including cheap and safe chemical engines, nuclear, electric/electromagnetic, fuel-free, including:

Electrodynamic tether engine

Solar sail based engine

Electric propulsion engine

Alternative approach engines

Hypersonic engines

Hybrid engines

B9.3. Advanced space power units and their elements, including solar panels, energy storages and converters.

V9.4. High speed data transmission systems based on radio and optoelectronic (laser) information complexes

V9.5. Space navigation systems based on ground and outer space facilities, including:

Manned spacecraft modules and surface coordinate timing and navigation system

Regional level coordinate timing and navigation system based on pico and nano satellites

V9.6. Architecture, standards, facilities and software for prospective control and monitoring systems that provide reliable spacecraft control along with design, test and run costs reduction, including:

Mobile station for telemetric data acquisition and director information transmission

Algorithms and software for telemetric data processing

Algorithms and software for automated mission design and planning

Mobile computer based integrated onboard control system

V9.7. Multipurpose robotic infrastructures with minimal ground control including:

Algorithms and software for controlling distributed robotic system consisting of a plurality of units ("swarm")

Orbital and planetary based self-assembling self-organizing robotic complex

V9.8. Different types of cheap and producible structural composites similar or superior to traditional structural materials , including:

Cellulose based structural materials

Structure elements, heat protective, highly porous materials and macro composites SHS production in space flight and vacuum conditions

Composite carbonfibre use in manned spacecraft pressurized module production

Carbon fibre composite substitutes development (including basalt fibre, stone filaments)

"Aerogel" technology based heat protective coatings

V10. LAUNCH COMPLEXES AND OTHER ELEMENTS OF COSMODROME GROUND INFRASTRUCTURE

This section priorities are nowadays targeted on vertical markets of government procurements. Their relevance is based on new Vostochny cosmodrome and accordingly fundamentally new infrastructure project implementation in Russia, as well as on the prospects of private launching sites development for different LV types.

In accordance with the above, ST&T Cluster priority technologies include:

V10.1. Cryogenic propellant handling procedures and methods.

V10.2. Procedures and methods for postflight maintenance and и prelaunch processing of prospective space shuttle systems

V10.3. Configuration and software development for LV's in-flight onboard component testing equipment and telemetric data analysis, used in the prelaunch processing.

V10.4. Fire-explosion safety system development for landed reusable stages post-flight maintenance

V10.5. Introduction of modular concept for rocket and space products development, based on the set of different universal modules configurations , designed as self-contained products.

V10.6. Automated control systems development for the rocket and space products processing using fiberoptic communication lines.

V12. GROUND CONTROL COMPLEX

The section includes the list of most important directions of ground control complex development that are considered essential to implement within innovative R&D designs that are looking for the Skolkovo Fund support. Innovative proposition of particular interest are targeted at advancing and/or adding new features that are oriented on international cooperation. Innovative propositions may be targeted on system problems, as well as on specific particular problems that are related with design and manufacturing of ground control complex key elements.

In accordance with the above, ST&T Cluster priority technologies include:

V12.1. Ground control complex development based on an international public tracking network with standardized T&C systems (ground stations and appropriate spacecraft onboard equipment), providing continuous tracking and real time LVs and spacecrafts operating, especially contingency operating from the launch time to the end of its intended application.

V12.2. Low site count and single-site geosynchronous spacecraft control technology development.

V12.3. Ground control complex hardware and software unification and international standardization.

V12.4. Control technology development based on GPS/GLONASS user navigation equipment deployment.

V12.5. Ground TT&C systems development, targeted on ground control capacity and speed of command increase, ground control facilities commercialization.

V13. SOFTWARE AND DATA SUPPORT IN THE FIELD OF THE SPACE ACTIVITY

The section includes the list of most important directions of software and data support in the field of the space activity development that are considered essential to implement within innovative R&D designs that are looking for the Skolkovo Fund support. Innovative propositions of particular interest are targeted at the development or adaptation of software complexes in the field of item life cycle management both as a whole and in its stages.

In accordance with the above, ST&T Cluster priority technologies include:

V13.1. Functional, engineering and technological CAD systems for rocket and space sector

V13.2. Project data and design management systems, PDM, SCM and CPC class software complex adaptation to the sectoral and corporate problem solving

V13.3. Automatic process control systems (PCS), and SCADA, CNC, CRM and IETM class software complex adaptation to the sectoral and corporate problem solving

V13.4. Management information & control systems (MICS), and ERP, MRP-2 and SCM class software complex adaptation to the sectoral and corporate problem solving

V13.5. Design, manufacturing and marketing operating management in the field of space activity, MICS and PCS integration platform design

V13.6. CALS (Continuous Acquisition and Life Cycle Support) technology supporting rocket and space products lifecycle(PLC)

V13.7. Cooperation platforms for different vendor automation equipment and AIS, different data management systems integration within a single information space, PLM-solutions adaptation for the sectoral and corporate problem solving

V13.8. Platforms and standards for cloud computing applications in the rocket and space sector

V13.9. Methods and facilities for process and management audit regarding IT applications in the field of the space activity

V13.10. Augmented reality hardware and software systems in the field of the space activity

V. ST&T Cluster Special Priorities

Space activity support technology in a short and medium term (Roscosmos propositions)

This direction priorities are primarily targeted at the applicants (Foundation participants) that are planning further development of Foundation funded projects both on a commercial and public funding (federal programs, etc.) basis.

PK1. Power generation technologies for micro and nanostructures and systems with the use of quantum effects, thermal and electromagnetic energy electron transfer;

PK2. Nanostructure based prospective power sources and accumulators, including nanostructure based solar converters;

PK3. Power systems based on regenerative energy accumulators of oxygen-hydrogen electrochemical generators;

PK4. Equipment and quality control facilities production and methods for safe fluid hydrogen production, storage and transportation;

PK5. Power generation and long distance transmission technology to supply ground, near-Earth objects, interplanetary explorations and on-planet research facilities for scientific problem solving in the adjacent and deep space.

PK6. Nuclear power stations to supply electric and thermal energy for unmanned and manned spacecrafts, and systems that reside on the celestial bodies, including on-planet labs and settlements.

PK7. Technologies for intellectual control and navigation systems design;

PK8. Information processing, storage, transfer and protection technologies;

PK9. Technologies for electronic component base development;

PK10. Technologies for microelectromechanical systems development;

PK11. Nanostructural materials;

PK12. Prospective nanostructure based functional materials;

PK13. Nanostructure based "intellectual" materials;

PK14. Optical and radio band ERS technologies;

PK15. Technologies for collection, processing and и distribution of information about mobile and immovable objects(cargoes) condition and location using domestic space systems (facilities);

PK16. Space information-navigation technology for road surfacing and engineering services conditions monitoring;

PK17. Satellite geoecological monitoring technologies for territories and waters in the areas of hydrocarbons production and transportation;

PK18. Geomagnetic activity space monitoring technology;

PK19. Hydrometeorological situation space monitoring technology;

PK20. Seismic conditions space monitoring technology;

PK21. Earthquake precursor detection technology based on satellite atmosphere monitoring;

PK22. Global ionosphere and ozone layer conditions and dynamics monitoring and forecasting technology;

PK23. Natural and technogenic disasters monitoring and forecasting technology.

PK24. Space biotechnologies for developing new generation of pharmaceutical products and producing crystalline protein substances, bioactive substances hyperproducer strains, large biopolymer crystals.

PK25. Software system for automated survey planning, ERS with account of hardware limitations, downlink points capabilities, constellation spacecrafts workload;

PK26. Software and data bases for decision making informational support for the subsystems of Unified system of prevention and response to emergency situations in space operation (subsystems ESiS-1, ESiS-2, ESiS-3);

PK27. Automated monitoring systems and hardware and software systems for collection, processing and storage of monitoring information related to critical objects operation, hazardous materials transportation, and facilities and cargoes protection from natural and man-made risks, as well as terrorism manifestations.

MIDDLE AND LONG TERM COMPLEX SPACE TECHNOLOGIES

This direction priorities were determined by experts primarily in the interest of establishing cooperative multipurpose Centers in collaboration of Skolkovo Fund with participants and partners.

Ko1. Targets and problems integration technologies within the framework of integrated space taskforces

Ko2. Orbital support technologies for long living spacecrafts;

Ko3. Spacecrafts open modular structure technology («LEGO-concept»);

Ko4. Complex design and technology concepts for new generation of competitive standardized space platforms of different dimensionality development;

Ko5. Technologies for optical and radio band ERS, and geophysical activity monitoring

Ko6. Technologies for developing highly reliable components and systems for space-rated onboard electronic equipment;

Ko7. Technologies for space nuclear power plants and their key elements development;

Ko8. Innovative technological solutions in the field of LVs and rocket engines, particularly using nanotechnology achievements

Ko9. Technologies for developing target-oriented onboard equipment, sensors, onboard electronic equipment, power supply systems for various application spacecrafts;

Ko.10. Complex hardware and software «packaged» solutions to provide space services to the end users;

Ko11. Technologies for developing life-preserving systems and facilities for the long term space explorations.

VI. ST&T Cluster Proactive Priorities

Unlike general and special priorities that are targeted primarily to support the initiative Foundation applicants and partners, in proactive priorities Cluster considers it useful and is especially active in participants involvement and innovative cooperative formats development (cooperative Centers, SkolkovoTech departments, web-solutions, etc.). In the long view it is reasonable to consider selecting priority directions for the project implementation with the direct order from the Cluster (Foundation) side. The proactive priorities are developed in day-to-day Cluster management cooperation with experts, sci-tech teams and communities, and are targeted primarily at the development of activity formats, providing for their further institutionalization in the central part of innovation ecosystem that is directly linked with Foundation structures.

Basic and exploratory research support

In this version of the document the list of proactively supported basic and exploratory research subjects include:

Pro 1. Space debris mitigation and recycling

Pro2. Asteroid and comet counteract

Pro3. Protected microelectronic components for space flight conditions applications

Pro 4. Nuclear power plants for space applications

Pro 5. Space solar power, including photoconverters

Pro6. Nanosatellite system solutions and technology

Pro7. Astronomical observation technology

Pro8. Suborbital space tourism

Pro9. Space propulsion units based on new physical principles

Pro10. New low-cost means of space cargoes delivery

Pro11. Prevention of space factors impact on biological objects

Innovative ecosystem development

In this version of the document the list of proactively supported innovative ecosystem development project directions include:

In1. Establishing national infrastructure of full cycle microsatellite technology which involves leading universities.

In2. Establishing national infrastructure and business development in the field of manned suborbital flights.

In3. Establishing specialized outsourcing engineering centers in the field of the space communication

In4. SkolkovoTech curriculum development, establishing multilayer educational environment based on the lead in the field of the space oriented education along with distance and network components

In5. Establishing national infrastructure for human capital assets development in the field of space monitoring applied technology that involves leading universities

In6. Establishing a system for accumulation and propagation of knowledge in the field of cosmonautics, space activity, high technology, and Universe and Earth science

In7. Establishing consulting centers for high tech industries

In8. Study on establishing public-private operator for the optimization of space and adjacent sectors participation in the space exploration and use projects.

In9. Establishing support mechanism for small and medium business and university teams participation in space research and applications, including a competitive basis

In10. Establishing a legal regulatory framework for the business activity in the field of cosmonautics

ST&T CLUSTER SUBJECT AREA EXTENSION

Upon a decision on extension of Space technology and telecommunication Cluster responsibility to include in its scope of activity also the aviation (aerospace) technology, it is reasonable to set in the first version the following priority directions of extended cluster activity:

A1. Aerospace and hypersonic systems, technologies and materials

A2. Manufacturing technologies, processes, materials, and software for the aviation and space industry

A3. Unmanned aerial vehicles for various applications, including balloons

A.4. Aerial Earth remote sensing

A5. Fundamental principles of aircraft engineering research and its commercialization

A6. Interdisciplinary and cross-sectroral research, targeted on the obtaining of conceptually new products and services in the process of aerospace and other sectors of science and technology cooperation

A7. Small aircraft based on alternative engineering solutions.

VII. PRIORITY SYSTEM DEVELOPMENT AND UPDATING

Priority system will be updated based on foresight procedure, its first cycle implementation was scheduled in 2012 Q1.

VIII. Glossary

Vertical markets – in the context of ST&T Cluster – are target markets for high-tech products and services limited by one or two sectors (rocket and space, aerospace), where in some instances the major customer is a government (oligopsonic situation). Institutional markets are subtypes of the vertical market. Examples of vertical market are launch services market, rocket engine market.

Horizontal markets – in the context of ST&T Cluster are the target markets for high-tech products and services that are not limited by specific sectors and are generally oriented at the mass distribution of replicated or adaptable products and services for not previously restricted range of customers. Horizontal market example is the market for satellite navigation systems GPS/Galileo/GLONASS subscriber terminals

Value chain is chain of transformations, passing through each transformation product gains some value – from row materials to the end user product. In the context of ST&T Cluster, sample value chain could be a transition from spacecraft components, systems and subsystems to the spacecraft package, and after that to the target-oriented space system and the end user services (communication channels, Earth imaging, etc.)

Upstream segment – in the context of ST&T Cluster – is a part of value chain and a correspondent plurality of organizations that provide space crafts development. The upstream segment includes rocket and space equipment manufacturers and launch services providers with their cooperation.

Downstream segment – in the context of ST&T Cluster – is a part of value chain and a correspondent plurality of organizations that provides space products and services to the end users. Downstream-segment includes satellite constellation operators , space products and services providers, space navigation and communication subscriber terminals manufacturers.

Committee of Cluster experts took part in preparation of version 1.0 of the Priorities. Overall project management – Candidate of Technical sciences S.A.Zhukov; Director of Science – Doctor of Economics, Candidate of Technical sciences D.B.Payson, Contributors – Doctor of Physics and Mathematics G.G.Malinetsky, Candidate of Technical sciences V.R.Anpilogov, Candidate of Technical sciences K.S.Elkin, Candidate of Technical sciences, MBA A.G.Ionin, Candidate of Philology. O.N.Kapelko, Candidate of Technical sciences A.M.Krylov, Test - Cosmonaut - M.V.Serov, A.Yu.Baurov, Yu.L.Leshkov, A.V.Potapov, A.M Romashkin, V.A.Rubanov, representatives of: leading scientific research institutes and enterprises of space branch, large companies of public sector, Yuri Gagarin Cosmonaut Training Centre, etc.