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Role of Skolkovo in the development of Russian private space industry

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Author :

Ivan Kosenkov

Skolkovo Foundation Space and Telecommunications Cluster, Russia

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Executive summary

The spaceflight is the very recent activity. Since the beginning of space age a number of milestones have been achieved. However, the current pace of space technology development is considered by many experts as ‘stagnating’. This process is explained through common ‘S-curve’ concept.The following dynamics of space technologies development predicted, referring to private ‘Space 2.0’ companies as the key element for a new stage of growth.

Space activities are designated by the Russian government as one of the priority areas of technological development. At the same time, Russian space sector haven’t seen much of private activities until recent establishment of new player – Skolkovo. The article observes tools, actions and results of its efforts to create innovative private space industry, changing institutional environment of national space activities – phenomenon never existed before in Russia.

Space technologies in a general technology development framework

The development of space technology faces the problem of decreasing speed of performance enhancement since 1980s. The high costs for orbital launch and consequent deployment of orbital infrastructure due to physical limits of chemical propulsion, expendability of launch vehicles, and hostility of the environment of outer space create the natural barrier for space activities development. The technological hurdles beyond spaceflight highly influenced the market, strongly dominated by government entities, possessing considerable amounts of resources and big industrial players, creating oligopolistic and oligopsonistic market with no will of players for any change. In the same time, the possible dual use of space technologies made the space activities even harder to enter for new players. Cold war era space race have done very much for spaceflight technologies development, but as soon as first milestones, such as Moon landing were achieved,the funding for further technological development was cut and stays relatively modest by the moment. Not to mention the fact that space hardware is often produced in small numbers and has a very high cost per unit.All of these factors have led to the current state of space technology development, characterized by experts as slow incremental rather than explosive. Launch vehicles, most part of satellites, manned space systems haven't seen any radical change since maturation of spaceflight technology. In the same time, it's clear that achievement of new goals in space exploration and utilization with current technological approach is hardly achievable and associated with multiple risks and massive expenditures[1].

However, there is still a cause for optimism. The general idea is that the development of space technologies is the subject to the general rules of technology development and can be analyzed in the framework of S-Curve, which illustrates the introduction, growth and maturation of innovations. In the early stages large amounts of money, effort and other resources are expended on the new technology but small performance improvements are observed. Then, as the knowledge about the technology accumulates, progress becomes more rapid. As soon as major technical obstacles are overcomed and the innovation reaches a certain adoption level an exponential growth will take place. During this phase relatively small increments of effort and resources will result in large performance gains. Finally, as the technology starts to approach its physical limit, further pushing the performance becomes increasingly difficult, as the Figure 1 shows[2].

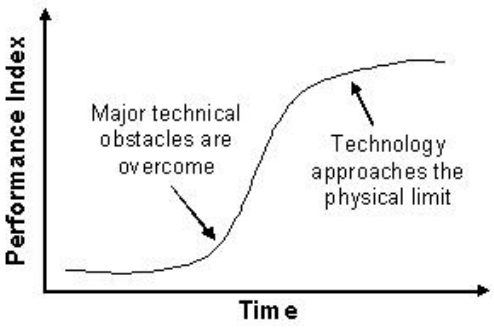

Figure 1 - Technological S-Curve: General framework for technology maturation

In order to solve the problem, radically new architecture for space assets must be adopted in order to create a new S-curve, shifted to the right of the original one, with a higher performance limit, shown on Figure 2. The question here is what can cause this shift to occur: what's the driver for next generation space technologies emergence?

1. For example: http://www.thespacereview.com/article/2733/1
2. http://innovationzen.com/blog/2006/08/17/innovation-management-theory-part-4/

Space 2.0 companies: a driver of technological breakthrough?

It is clear that for traditional government oriented space programs existing performance of technologies, in absence of cold war driven space race, are quite sufficient. In this situation only the new breed of players focused on radical extension of space market can make the difference, giving the demand for new technologies in order to outperformthe giants of aerospace industry. These so-called “Space 2.0 companies” with its flexible approach are currently discovering and exploring new business models and new markets for space activities.

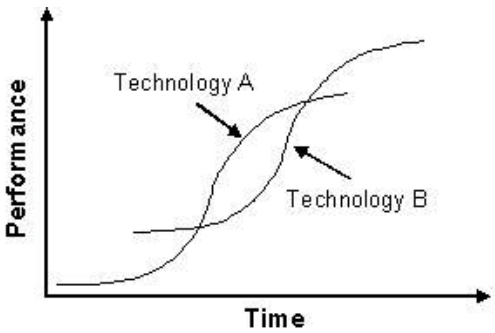

Figure 2 – Restart of technology progress after shift to the new S-curve

Originated mostly from IT-industry, these new players apply the approaches specific for IT with higher rate of iterationsfor performance enhancement to space systems architectures. In the framework of this approach, they are more committed to the search of innovative solutions than to the traditional space industry paradigm, reducing the pace of innovations - “If it ain't broke, don't fix it”.

For the most players of private space industry cheaper equals better.Lowering the price barrier has attracted to space activities multiple small and medium enterprises, university teams, companies from developing countries.

Affordable solutions allow highly iterative product development process with constant performance enhancement. Those solutions include new engineering approaches (ex.: use of additive manufacturing) or use of standard commercial components and common architecture (ex.: a plethora of companies using cubesat architecture with “commercial off-the-shelf” components) or development of less performant solutions, fitting the demand of other market segments (ex.: light launch vehicles with performance of several dozen kg. to low Earth orbit).
In the same time the new engineering approaches must not decrease the system performance as a whole. For example, for satellite systems decreased operational lifespan is compensated by great numbers of satellites in constellation, cheap to produce and launch, thus making the whole system redundant. The search for new affordable and reliable solutions for space systems increases general space technology development pace.

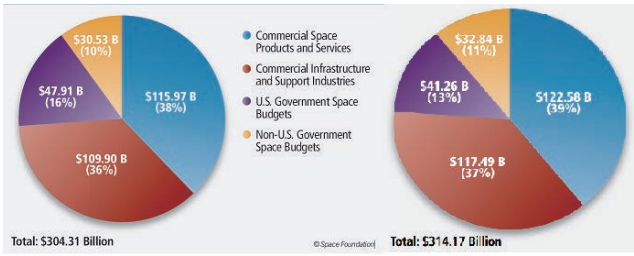

Figure 3 Space market dynamics 2012-2013

New space systems are using the distributed network-centric architectures. The particular solutions refer to trendy IT domains such as Big Data and Internet of things, allowing the development of new space-based products and services, opening new markets with new customers. One more trend – the use of complementary systems: UAVs for earth observation and telecommunications, ground-based augmentation systems and beacons for navigation. The combination of data received from different systems allows the emergence of new products.

The need for cost efficiency enables new business models for space companies. Space 2.0 startups are vertically integrated: from space hardware manufacturing to the services provided to customers, they switched to provision ofadded value services from their own-built space assets. The space market now is not about satellites and rockets – it's about data (Figure 3[3]).

In spite of this, time accurate and precise data require more space-based assets, pushing the space infrastructure market to growth. It pushes the research for new launch vehicles and spacecraft architectures. Still, Space 2.0 environment sticks to the strategy of technology push, hoping that eventually the critical mass of innovations will make the next generation infrastructure feasible and affordable, restarting intensive space technology development and creating more markets for space activities. Space 2.0 hype, pushed by IT enterpreneurs, founding their space companies,makes space activitiesattractivefor investors and new companies with the ideas on the verge of feasibility, such as space mining enterprisesPlanetary Resources and Deep Space Industries, planning to extract resources from celestial bodies.

Still,the proper measures of government support matter for private space activities. There are multiple options to foster space technology research. Those include industrial policy, technology transfer programs, public-private partnership initiatives, grant funding of private research. Without NASA contract, SpaceX wouldn't achieve such a tremendous success – public agencies are still the only client for manned spaceflight missions; without government established Global Navigation Satellite Systems, navigation applications developed by private companies wouldn't exist. General trend – public entities are becoming regulators and customers for the private space companies, performing by themselves only the missions that haven't any commercial potential (e.g. space exploration, science).

Institutional environment for space activities in Russia

Until recently, private space sector in Russia was an oxymoron. At national space agencyRoscosmos board meetings, general managers insisted that space exploration was a government matter. Only rare heretics dared to state that astronautics can be profitable.Main players in national space industry were companies with strong government participation. On the other hand, their customers were public agencies (Ministry of Defence) or big industries (Gazprom). Roscosmos, was at the same time the regulator, the customer and the contractor for space activities.

The industry was under the direct control of space agency and vice versa – the formation of long-term national space program by space agency was determined not by the needs of customers but by the interest of saving national space industry from decay. It has allowed to Russia to save national space industry relatively intact in conditions of severe budget cuts in 1990s but in the same time conserved an archaic institutional environment inherited from MOM (Ministry of General Machine Building). This structure was relatively efficient in socialist economy environment, allowing it to achieve a number of great firsts in space exploration, but in new conditions it hindered innovations[4].

Space industry in general wasn't customer oriented and wasn't motivated to produce competitive products and services. In the same time, national space policy was oriented to support only major enterprises, giving it all the R&D contracts. The structure of Federal Space Program, main document defining the development of

3. Data combined from "The Space Report 2013" and "The Space Report 2014" by Space Foundation
4. More information here: Makarov Y, Payson D, Russian space programmes and industry: Defining the new institutions for new conditions, Space Policy, vol.25 issue 2, May 2009, pp. 90-98

national space sector, had a rigid structure, making hard to allocate funding for innovative research. More to add, the structure wasn't friendly to technological transfer. As a result most part of breakthrough technologies, developed for space program (example: Buran space shuttle) remained unused until becoming obsolete.

As for space applications, national space assets were usurped by the military. The dissemination of space-based data received from Russian orbital constellation faced multiple restrictivebarriers and absence of commercialization mechanisms. It explains why the first satellite imagery providers, like Scanex, were using raw data received from European and American satellites. The other reason for this is the loss of competitiveness of Russian satellites in terms of quality of provided data, lifetime, cost and manufacturing period.

Funding increase for national space program that occurred in 2000s wasn't efficient – a row of resonant failures of launch vehicles and spacecraft showed that the upholding of position of leading space-faring nation requires much more effort than the simple additional funds allocation. Depletion of human resources and technological reserve of industry, lack of vision for the national space program can be considered as the causesfor systemic crisis in the space industry. The solution was found – an institutional reform intended to improve the institutional environment making it favoring to innovations and new players involvement by enabling public-private partnership and open innovations frameworks. The idea is that competitive environment will result in the increase in technology improvement rate, quality of provided products and services thereby closing the technological gap. Some of private players were already there: data providers launch operators who worked much on deregulation and making space industry attractive for private players. The example for such struggle is long litigation led by Scanex to remove the restrictions for high resolution Earth observation data.

Skolkovoas a basis for private space industry formation

Still,open the industry for the new players and wait them to come is not enough. Systematic approach is needed to breed new space companies. The mechanism supportingthe formation of private space sector must provide new companies with favorable conditions for development, investment attraction, GR and PR support, ground and equipment to develop the product, source of qualified human resources. In other words, the goal is to create an ecosystem of private companies interacting with each other, developing the competitive products for space markets value chains, shown on Figure 4: from components and subsystems for spacecraft to software platforms using space data to provide added values services to end users. The number of players in the ecosystem must reach a "critical mass" sufficient for the creation of significant impact to Russian space sector and increase of Russian share of international space markets.

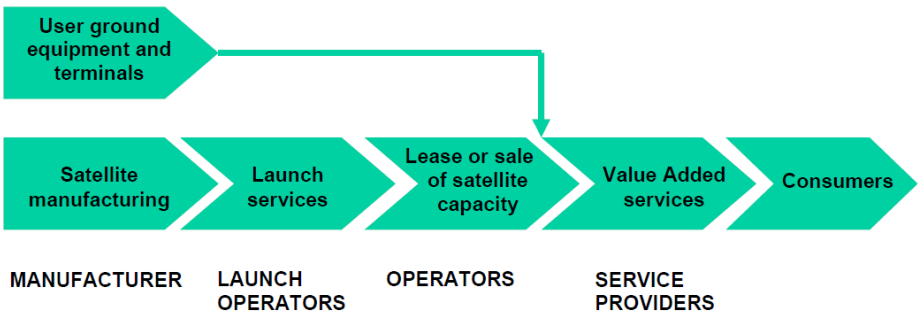

Figure 4: General view of space value chain

One of the measures allowing meeting of such requirements is the establishment of various development institutions. Those who existed in Russia were focused on the other domains of technology or supported the fundamental scientific research rather than high-tech business. The new development institution, named Skolkovo Foundation, was founded in 2010.

Charged with providing the catalyst for the diversification of the Russian economy, the Skolkovo Foundation's overarching goal was to create a sustainable ecosystem of entrepreneurship and innovation, engendering a startup culture and encouraging venture capitalism.

In addition to space technologies,Skolkovo Foundation focused othertechnology domains, identified as "growth points" by expert community: energy efficiency, strategic computer technologies, biomedicine and nuclear technologies. The feature of Skolkovo is the focus on support of companies, developing the technologies rather than on pure science – Skolkovo doesn't decide what particular research must be conducted, only checks its consistency with own technological foresight. The most important feature - Skolkovo was the only one development institution having support of small private space businesses as a focus.

In order to create an ecosystem of private space companies, Skolkovo Space cluster has performed multiple actions in various directions. First was to give small companies the favorable conditions for the business growth. The general Skolkovo framework, providing tax benefits, access to venture investment, technologies of industrial partners and grant funding was a first step attracting the entrepreneurs to start their business in one of the domains, supported by the cluster.Here is the list of these domains:

- Satellite applications, including satellite navigation, Earth observation and Earth remote sensing;
- Small spacecraft technologies;
- Spacecraft systems, subsystems and components;
- Ground infrastructure for space activities;
- Industrial and manufacturing technologies for aerospace industry;
- New materials for aerospace applications;
- Orbital and suborbital launch systems;
- Unmanned aerial vehicles and its applications;
- New telecom technologies, including those for wired and wireless telecommunications;
- Software and hardware for telecommunications.

Space cluster has become the point of attraction for building up the strong community of entrepreneurs, experts, scientists, investors thus creating an ecosystem of private space businesses. It provides the platform for dialogue between public and private players trying to find the points of contact with each other.

The second was to initiate a tectonic shift on institutional level of space activities, making the environment more susceptible to new approaches, coming with new market entrants and new services. In the very beginning of Space cluster activity it has development an efficient framework for collaboration with Russian Space Agency (Roscosmos) setting up the favorable conditions for small and medium enterprises activities in space domain, particularly regarding license for space activities issued by Roscosmos. More to add, some of the Russian space market majors such as NPO "Energomash" and ISS Reshetnev have founded spin-off companies in the Space cluster focusing on R&D activities. Vice versa, Space cluster residents have gained a possibility to participate Roscosmos programs and tenders. Space cluster has also obtained access to industry expertise in project evaluation through cooperation with Roscosmos. These activities resulted in strengthening of Space cluster position as an independent center of competencies for elaboration of Russian space policy, particularly of public-private partnership in space activities. Skolkovo experts made a significant impact to the reform of space sector by bringing new approaches to the general vision elaborated by experts.

The third was changing the way of thinking for participants, making them more opened towards an international market, new way of doing business. Space cluster consequently enforced demand driven approach to research activities among its residents, bringing venture capitalist logic to a conservative sector. The issue here is that big part of Russian entrepreneurs trying to start private space company frequently concentrate their efforts on technology, rather than the product. Without the vision of the market and customers, the companies are stillborn.

Fourth, taking into account that space startups can thrive only focusing its activity on international market, Space Cluster has a permanent interest in strengthening cooperation with innovation support institutions and space startups worldwide, looking forward to establish close connections with science and technology parks, hosting space startups, proposing them soft-landing in Skolkovo and providing them with grant funding and acceleration for Russian market access. The strengthened collaboration between Skolkovo residents and foreign companies can lead to establishment of globally competitive joint ventures.

Cluster also envisions the involvement of the major aerospace players into ecosystem, as key partners with the possibility to establishresearch centers in Skolkovo. The partnership with such international industry giants as Airbus and Boeing in landing some of its R&D inSkolkovo brought an international dimension in Cluster activities. It is supposed that leading aerospace equipment manufacturers will be interested in technologies developed by Skolkovo startups, thus becoming strategic investors for some of the companies.

Last but not least is the expertise in the space domain and the vision for the future space technologies development elaborated with the help of experts in space industry.

This vision describes the possible directions of technological improvements, creating new markets or enlarging existing ones. This results in the search and support of the companies working on products and services that can potentially change the way we explore and use outer space. Space cluster divides it into two big groups: technologies of incremental growth and potentially disruptive technologies. First ones are enablers for the second group

•Satellite communications: emergence of High-throughput satellite communications services, return of LEO telecommunication constellation, new players on the market

•Earth-observation: further growth of services based on Earth observation data, increase of the temporal and geospatial resolution of the data. Multiple layers for Earth observation: UAV and satellites are being used together.

•Satellite navigation: signal accuracy enhancement, integration with ground based augmentation systems, integration with geoinformatic systems (GIS). Compatible and interoperable global satellite navigation systems.

•Small satellites: replacement of big, expensive satellites with constellations of cheap interoperable network-centric spacecraft

Technologies of new level, enabling long-term goals of space exploration and utilization

•Reusability of launch vehicles: re-used stages of launch vehicles, hybrid propulsion, hypersonic aircraft, air launch

•Additive technologies: zero-g space manufacturing, space infrastructure of the new level, applications for the increase the efficiency of space industries

•Roboticservicingtechnologies: service and upgrade of orbital assets, removal of space debris

•Space resources utilization: comets and asteroids can be used as raw material for building space infrastructure, the source of rare-earth metals or propellant

•Space tourism: increase of reliability of suborbital launch vehicles, fast suborbital transportation services, the

development of tourist infrastructure (ex.: orbital hotels)

The result of Space cluster activities is an ecosystem of more than 100 companies in various technological domains related to space activities: from development of launch vehicles and satellites to new applications and productsusing space data. Skolkovo support allowed them to find investments, partners and clients on the world markets.
•Dauria Aerospace, whichhad won a tender worth RUB 310 million in 2012 for creating two small space vehicles for Roscosmos.In 2014, the company built and launched the DX1 satellite in Russia and two Perseus-M micro-satellites in the US. These maritime surveillance satellites provide automatic ship identification, and serve as technological test beds for future platforms and equipment. Future projects of Dauria include a high-resolution Earth observation satellite and two all-electric small geostationary telecommunications satellites for indian customer Aniara Communications.

•Sputnix on 20 June 2014 it launched its micro satellite, TabletSat-Aurora. This spacecraft has become the first private satellite built and launched in Russia. The novelty of the project is application of so-called “LEGO ideology”. Satellitesubsystems are connected to the central bus through “plug and play” interface: all of the platform’s service systems include a common service interface, which allowsbuilding the satellites from standardized blocks.Sputnix hopes that TabletSat-Aurora will become a universal platform for the different payloads. The company plans to build an Earth observation constellation of several small satellites providing high-resolution (1 meter/pixel) imagery.

•Spectralaser, have successfully entered in space industry value chains improving the efficiency of existing products. It develops laser ignition modules for rocket engines. The company successfully tested the product on liquid-fuelrocket engines of Soyuz launch vehicle. Those modules supposed to ignite all engines of the rocket that will be launched from newVostochnycosmodrome in 2016. The research is conducted in close cooperation with several industrial partners: Keldysh Center, NPO Energomash, ChemautomaticDesign Bureau, JSC SRC «Progress» and Kuznetsov JSC.

•Azmerit provides innovative solutions in small-scale star tracking devices for attitude control of micro satellites;

•KosmoKurs develops the reusable suborbital launch vehicle for tourism and scientific experiments.The system includes multi-level emergency protection system ensuring safe and low-cost suborbital flight for passengers. After initial operations, launch vehicle for small satellites planned to be developed based on the system. The stage of flight proven prototype supposed to be achieved until 2020.

•Lin Industrial is developing a family oflight launch vehicles for small satellites launches that could drastically reduce the costs of access into space.
Cluster supports the companies developing added values services based on GLONASS signal and data from Earth sensing satellites.

•WayRay named by Forbes among ‘6 Tech Companies Disrupting The Daily Drive’, develops augmented reality technology for vehicles using universal windshield coating combining the features of smartphone, navigation device and head-up display.

•SPIRIT Navigation develops hybrid navigation technology for seamless positioning indoors and outdoors. The core of product - hypersensitive software for GLONASS-GPS signal reception, ensuring sensitivity 5 times higher than the world market leaders.

Some companies developing products for space, such as solar batteries, power elements, new materials have found new markets on Earth. The important result of ecosystem building activities was the collaboration between cluster residents.

•RoboCV has developed an autopilot system for warehouse equipment X-MOTION using its research on Moon rover for Google X-Prize contest. The product is tested on Samsung, Volkswagen, Magnet warehouses. The company raised more than 100 million rubles of venture financing;

•Energy storage management systems (SUKhE) developed automated optimization systems for energy-efficient use of autonomous power sources for the transport and energy applications. Initially designed for ground segment of space systems, the system is now successfully tested to be applied on new electrobuses developed in Saratov.

Still, cluster and his resident companies face numerous challenges after several years of its activity. First is high entry barrier for space businesses in Russia: rocket science is still expensive and time consuming. The big project such as launch vehicle development is hard to fit into Skolkovo framework. In the same time, it's difficult for startup to find their place in the space industry value chains, especially in the period of institutional reform of sector. The customers, contractors, even the regulator are experiencing the turbulence of mergers between each other and sector governance hurdles.At the same time the big part of Russian venture investors remain reluctant to participation in risky space projects, demanding massive cash infusion during long periods. Also the number of investors having the sufficient expertise in space business remains relatively low.

Conclusion

To sum up, Skolkovo Space cluster enabling role for private space activities in Russia is quite obvious. The team of the cluster was able to meet its initial goals in building "Space 2.0" ecosystem in spite of numerous challenges. Evolving institutional environment of national space activities is a great opportunity for Skolkovo to reach an ambitious goal of fostering the establishment of national self-sustaining private space sector.
The success will bring the necessary impetus to the national space sector, both in technological and organizational sense. Companies bringing their solutions into traditional value chain will increase the competitiveness of products of space industry and in the same time will create healthier, more dynamic and competitive market.
According to the general framework of technology development, the evolution of space technologies eventually will bring us to breakthrough, allowing the significant market expansion and development and launch of the next generation space infrastructure, shifting to the new s-curve of technological development, allowing the humanity to begin a new era of space exploration.