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**Russian Robotics:
Jumpstarting to re-industrialisation with Skolkovo**

Parallel Session 1 :

The impact of technology - Embracing innovation

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Russian Robotics: Jumpstarting to re-industrialisation with Skolkovo

Executive Summary

Intelligent robotics is a hot topic for modern academics, capitalists and policy makers. Yet, it still fails to fulfill its potential to increase productivity, improve life for the elderly and safeguard humans from accidents. Intelligent, or advanced, robotics (IR) has every chance of becoming the next general-purpose technology like energy generation, the Internet or mass transit. Such GPTs are industries in themselves, but they also enable other industries to emerge. Being a renowned center for tech expertise, Skolkovo has defined a set of four priority areas in IR: improving cognition/navigation; natural human-machine interfaces; human augmentation systems; and medical robotics. Based on this set of priorities for Russia's technological superiority, the Skolkovo Robotics Center (SRC) is capitalizing on the vast talent pool in Russia, especially in engineering, creating new opportunities for startup companies involved with robotics. Based on the lessons learned during Skolkovo's development, this paper offers a general model of applicability and scalability of the Skolkovo experience elsewhere.

Robotics as one of the next General Purpose Technologies

The basis for modern economic science is a combination of three major concepts: labor, capital and technology. However, the last one, technology, became a widely accepted chapter in economics textbooks not so long ago. In the Karl Marx age, technological advances were not that significant as to be noticed immediately by scholars and society in general. But nowadays we are facing paradigm shifts in areas such as computing almost every ten years. The speed of such changes can be put down to Moore's Law – “the doubling every two year in the number of components per integrated circuit”¹. Technologies open new markets faster than ever before in human history, and often technology solves some global societal and economic issues. It is often noted that there is a special class of technologies that has a deeper impact on civilization. This class of technologies is referred to as General Purpose Technology² (GPT) – the technological equivalent of universal utility item – sought-after technology by countries and peoples that affects everybody. It is not only a market in itself, but it is a market that makes tools for other markets. It is very similar in effect to modern mass transit systems, energy grids or the Internet. These technologies are shaping modern civilization. Wikipedia has already listed control theory, which is basis for automation and robotics, as one of the already-established GPTs. Robotics could provide the answers to some of our most fundamental challenges: productivity growth, the aging society, public safety and disaster response. Thus, there is a significant probability of robotics becoming the next GPT with a very broad impact on all aspects of society. This is already popularly acknowledged: Robotics is entering public discourse on a scale unseen before. Researchers indicate a 16-fold increase in references to robotics in headline news, in English, over the last five years³.

Worldwide spending on robotics is rising, according to various estimates from market analysts. For example, BCG has juxtaposed various markets estimates in one diagram (Figure 1). It plots the predicted growth of robotics over the next ten years for four key market applications: personal, commercial, industrial and military⁴.

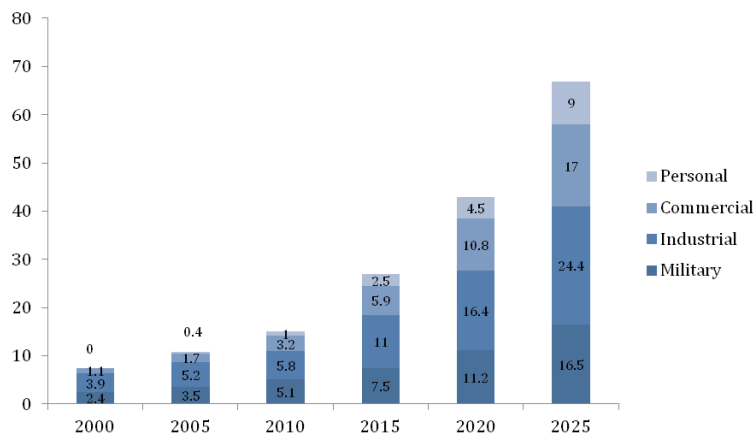


Figure 1. Total robotics market value estimation in USD billion through 2025

1. <http://spectrum.ieee.org/tech-talk/semiconductors/devices/five-things-you-might-not-know-about-moores-law>
2. Helpman E. General Purpose Technologies and Economic Growth, The MIT Press, 1998
3. http://www.nesta.org.uk/sites/default/files/our_work_here_is_done_robot_economy.pdf page 6
4. <http://www.bcg.com/media/PressReleaseDetails.aspx?id=tcm:12-169388>

What is a robot, anyway?

With the public and scientific discussion of robotics on the rise, defining what exactly a robot is will set the course for further academic debate. There are three possible approaches to the definition: anecdotal, provisional and industrial. The anecdotal approach is an empirical one that basically sides with the experts (self-proclaimed or otherwise). Some experts claim that a robot is 'any machine that automates physical tasks'⁵. The ultimate expression of this opinion follows Dilbert's approach – 'to call a robot anything that robotics experts call a robot'. This is by far the most popular approach to defining robotics in all circles. Yet, it leaves a lot of space for manipulation, and therefore is unsuitable for policy making processes.

The second approach, provisional, claims that robotics is not technology in itself, but actually a stage of technological maturity. Proponents of this definition tend to call whatever is in the laboratory, or in a trial, a robot. However, as soon as it leaves the lab to enter the commercial market, 'robot' is no longer a valid description. The main argument for this definition is negative-based: 'We don't call modern vacuum cleaners robots, even though 'roomba'-like machines, in fact, originate in robotics technology'. This definition, however, is also very difficult to put to use for any extended technology policy.

The third approach, industrial, is the most widely accepted among robotics professionals and has potential for further application into the area of policy making for robotics research. According to this approach, one may call a robot any object which correlates with the ISO standard definition⁶:

- A robot is an actuated mechanism programmable in two or more axes with a degree of autonomy, moving within its environment, to perform intended tasks. Autonomy in this context means the ability to perform intended tasks based on current state and sensing, without human intervention.

ISO also defines some high-level categories of robots:

- An Industrial robot is an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications

- A service robot is a robot that performs useful tasks for humans or equipment excluding industrial automation application. Note: The classification of a robot into industrial robot or service robot is done according to its intended application.

- A personal service robot or a service robot for personal use is a service robot used for a non-commercial task, usually by laypersons. Examples are a domestic servant robot, an automated wheelchair, and personal mobility assisting robot.

- A professional service robot or a service robot for professional use is a service robot used for a commercial task, usually operated by a properly trained operator. Examples are cleaning robots for public places, delivery robots in offices or hospitals, firefighting robots, rehabilitation robots and surgical robots in hospitals. In this context, an operator is a person designated to start, monitor and stop the intended operation of a robot or a robot system.

- A robot system is a system comprising robot(s), end-effector(s) and any machinery, equipment, devices, or sensors supporting the robot performing its task.

5. http://www.nesta.org.uk/sites/default/files/our_work_here_is_done_robot_economy.pdf , page 6

6. ISO 8373:2012 Robots and robotic devices. http://www.iso.org/iso/catalogue/catalogue_tc/catalogue_detail.htm?csnumber=55890

Driving the Rise in Robotics

Steven Johnson thoughtfully noticed that true innovation solves more than one task⁷. Robotics answers three global challenges: declining productivity, the aging population and disaster handling. These three drivers are discussed in detail below.

The Productivity Race

So, the first reason for a so-called 'robotics renaissance' is rooted in the constantly increasing competition among countries in productivity and manufacturing efficiency. The arms race of the second half of the 20th century gave way to a 'productivity race' involving more than two countries: China, the US, Europe, Japan and others are competing to be the nation with the highest productivity. The world's biggest economies now battle it out to see which can deliver more goods or services, expending the fewest resources along the way. Universal digitization and connectivity, along with cheap computing and sensors, have paved way for a new means of increasing productivity. This state of affairs has even been referred to as the 'second machine age' by academics E. Brynjolfsson and A. McAfee⁸, who note the 'first machine age' empowered humans by increasing their physical capabilities with steam engines, electricity and nuclear power. The second machine age, they say, will empower humans with intelligence capacities in the same way that steam engines boosted brute force. The impact of robotics and, more broadly, digital manufacturing on lifestyles, healthcare, society, the economy and governments is going to be very significant over the next 10 to 15 years, likely running into the trillions of US dollars. There are three basic drivers behind these dramatic trends. At first, we have the productivity race. This is crucial for modern nation states for all economic activity, but increasing capital and labor productivity in the manufacturing sector seems like the very top priority for the major players in this race. Boosting productivity is the biggest incentive to automate for manufacturing industries all over the world in order to be competitive in global markets. Interestingly, this is true for all types of markets: developed and developing. An annual report published by the International Federation of Robotics draws a very comprehensive list of economic needs that make further automation inevitable in the new manufacturing paradigm⁹:

- The demand for consumer goods is increasing everywhere, and especially in the emerging markets.
- Product lifecycles, especially in consumer industry, are decreasing.
- A shorter time-to-market for technological innovations is needed.
- The demand for high-quality products and sustainable solutions is rising all over the world.
- The increasing diversity of consumer goods requires a sound, flexible production system to adjust the production process in order to meet demand without compromising quality.
- Automation and increased productivity are required to offset labor (and skill) shortages caused by demographic shifts in several countries - and the higher costs associated with an over-aging society¹⁰.

Robotics is a key component of automation regardless of the particular industry. The major reason for adopting robots is to increase the efficiency of equipment usage. However, the full economic benefits are summarized among the following areas¹¹:

- Increasing production output rates. Robots can work at a consistent speed 24 hours a day, seven days per week. Robots can be programmed to handle new products offline, ensuring faster production of new products.

7. Johnson S. Where Good Ideas Come From: The Natural History of Innovation, Riverhead Books, 2010

8. Brynjolfsson E., McAfee A. The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies. MIT Press, 2014

9. Industrial Robotics 2014. International Federation of Robotics, www.ifr.org

10. This last one is very well illustrated in short video <http://www.nytimes.com/2015/04/25/technology/robotica-cheaper-robots-fewer-workers.html?src=xps>

11. Taken from Industrial Robotics 2014. International Federation of Robotics, www.ifr.org

- Improving product quality and consistency. Robots are precise and consistent. They can continuously produce high-quality, finished products.
- Increasing flexibility in product manufacturing. Robots can provide flexibility to the production line. Once the required processes are programmed into the robot controller, it can easily switch from one assignment to another, performing multiple tasks for a variety of products.
- Improving working conditions for employees. Robots can improve working conditions for staff. Dangerous, tedious and unhygienic work is transferred from human to machine. Not only is the environment is cleaner for the worker, but the job is also less physically fatiguing. In addition, by educating workers on how to use robots, they can learn valuable programming skills and perform more stimulating tasks. By using robots, the likelihood of accidents caused by contact with machinery or other potentially hazardous production processes can be reduced. They can also help eliminate ailments associated with repetitive or intensive processes, such as repetitive strain injuries¹² and vibration white finger¹³.
- Reducing material waste and increasing yield. Using robots increases the volume of finished products that comply with the required standards. Therefore, the amount of breakage and waste produced as a result of poor-quality or inconsistent finishing is reduced. Attaining high-quality products and reducing waste at the same time will result in greater yield.
- Saving space in high-value manufacturing areas. New industrial robots are reducing space requirements and opening up whole new fields of potential applications in production – even in confined spaces. They even enable compact cell layouts in the high payload range. The lighter components of the robots allow greater dynamic performance and even shorter cycle times, as well as being more flexible than before. Lightweight robots with lower payloads offer more flexibility, i.e. they can be placed also on the ceiling or the wall.
- Reducing costs. Using robots has a positive impact on the reduction of the cost of consumable goods. By increasing the speed in production, businesses can better predict the production rate and ensure that a swift and efficient service is delivered. Direct and overhead costs can be reduced, e.g. energy costs. New generations of industrial robots with new control systems reduce energy consumption.

Service robotics and the benefits

As ISO's standard divides robotics into industrial and service, service robotics benefits are distinct from the benefits described above for the applications of industrial robotics. The International Federation of Robotics compiled a set of good indications where benefits can be found for introduction of service robots.

Table 1. The economic benefits of service robotics¹⁴

	Factors	Potential consequences for		
		Domestic user	Professional User	
Benefits	Higher work quality and productivity		higher product quality less material waste / less rejects	
	Reduction of manual work	more leisure time	less salary payments	
	Increased safety, risk avoidance	higher quality of life	lower salaries for dangerous professions	less work accidents causing non-productive time
	Increased operational availability, temporal flexibility		higher output / higher throughput	lower energy costs
	New, previously unavailable service	higher quality of life	unlocking / developing new markets	
	Status, PR effect	higher quality of life	image of an innovative enterprise	increase of public awareness

12. Occupational overuse syndrome, non-specific arm pain

13. An industrial injury triggered by continuous use of vibrating hand-held machinery

14. Service Robotics 2014. International Federation of Robotics. www. ifr.org

The Aging Population

The second major cause of the robotics renaissance is the need for a solution to caring for aging societies. It has been established that the population is aging rapidly in developed countries like the US, Germany and Japan. But from the other end, opportunities arise for countries with younger populations like China or Russia. Japan is a popular example of such trend: those aged 65 and older make up a full quarter of the country's population. It is expected that this number will grow by 10 percent to 35 million by 2025, and by 2050, 39 percent of all Japanese will likely be over 65¹⁵. Today, Japan's overall life expectancy average is 84.5 years, among the highest in the world. According to the Japanese Health, Labor and Welfare Ministry, an estimated 2 million nursing care workers should have been employed in 2010, but the actual number was 1.33 million - a 34 percent deficit. The ministry predicts a need for 4 million care workers in 2025¹⁶ because of its rapidly aging population. But as Japan's population greys, so too do the country's healthcare workers, a factor complicated by an already relatively low doctor-patient ratio of 2.2 physicians per every 1,000 people. The United States is no exception, even given the high level of immigration. The ratio of retirees to workers in the US alone is expected to reach 40 percent by 2020. According to the US Health and Human Services Department, there will be 72.1 million Americans over the age of 65 by 2030, which is nearly double the number today. According to the Bureau of Labor Statistics, the country will need 70 percent more home aide jobs by 2020, long before that bubble of retirees. But filling those jobs is proving to be difficult because the salaries are low: in-home aides make an average of \$20,820 annually¹⁷.

An age gap also creates shortages of highly qualified staff for manufacturing in developed economies. A McKinsey study in Germany predicts a shortage of 6 million skilled laborers by 2020, and highlights a pressing requirement for an increase of productivity. Another example is the shortage of 210,000 professional welders as at 2010 in the US, reported by the American Welding Society¹⁸. An estimate in the average age of workers in the automotive industry comes from BMW, which states that by 2020 around 45 percent of its workforce will be over 55¹⁹. One has to remember that the automotive industry has the highest density of robots. The aging workforce in auto-manufacturing will lock in the rise in demand for robots.

Replacing humans in dangerous (or dull) jobs

The third catalyst for the robotics renaissance, natural hazards or human-instigated disasters such as Fukushima, require fast, reliable and safe for humans tools to minimize or eliminate their consequences. Labor itself is can still be very dangerous to humans. Statistics from the World Labor Federation claim that, worldwide, 6,000 workers are killed on the job every day; 2.3 million people a year are injured, fall ill or are killed in the workplace; 160 million accidents take place at work per year; and 340 million occupational diseases are contracted every year. Robotics has obvious benefits by removing humans from immediate danger to save lives and maintain wellbeing. This will increase general social wellbeing.

15. Service Robotics in Japan, Foreign and Commonwealth Office Report, 2012

16. <http://bangordailynews.com/2013/04/29/health/japan-to-promote-robots-for-nursing-home-care/>

17. NYTimes: Helper Robots Are Steered, Tentatively, to Care for the Aging <http://nyti.ms/15YOVVP>

18. Executive Summary Strategic Research Agenda for European Robotics http://robotics.h2214467.stratoserver.net/cms/upload/Material/Executive_Summary_European_Robotics_SRA_small.pdf

19. Daily Mail: Built by Mature Workers: BMW opens car plant where all employees are aged over 50 <http://www.dailymail.co.uk/sciencetech/article-1357958/BMW-opens-car-plant-employees-aged-50.html>

Disaster-response and recovery is another area of application for robotics. It is an established fact that even though Japan is second globally in robotics density and boasts many robotics centers, it was solely the work of humans that led to crucial gains in controlling the spread of radioactivity following the Fukushima disaster²⁰. There are a number of robotics projects focused on disaster-response and recovery inspired by the Fukushima experience²¹.

Technology foresight as an instrument to focus on robotics perspectives

Just as important as doing the right thing is doing it the right way. Robotics is an interdisciplinary field with many cross-research areas and a lot of interdependencies. In order to make sure that arising opportunities are effectively explored through an entire innovation ecosystem, policy makers are in need of special instrumentation to prioritize focus areas. Foresight is widely recognized by academics and practitioners as a way to endorse changes in the implementation of innovation policy. There are many definitions of foresight. One, the most widely used one in relevant literature, is taken from EU Foren Guide and emphasizes the process and policy dimensions of foresight, defining it as a “systematic, participatory, future intelligence gathering and medium-to-long-term vision-building process aimed at present-day decisions and mobilizing joint actions²²”. According to a recent paper from NEST²³, there are two distinct forms of technology foresight activity:

There is foresight for/in policy, relating to its advisory and strategic function, where foresight serves as a tool to inform and develop policy in any area or to “join up” policy across domains.

Secondly, foresight as a policy instrument relates to its instrumental role, where it serves as a tool to implement budgetary, structural or cultural changes in the domain of research and/or innovation policy.

Here our focus is on the second application of foresight activity – an instrument of change policy for an innovation system. In more detail, foresight instruments can be useful and beneficial for following applications:

- Making an overall strategic review and direction of a national, regional or sector innovation ecosystem;
- Identifying priorities for research or innovation actions, again at multiple levels;
- Building common visions between innovation actors and/or stakeholders who may not be used to working together (e.g. industry-academic, procurer-supplier or different sectors in clusters);
- Making decisions more robust through exploration of scenarios or drawing in wider expertise;
- Increasing the likelihood of consensus by engaging a wider range of stakeholders through participatory elements.

There are numerous case studies on how foresights have been used in making innovation ecosystems and in creating sets of priorities for science, technology and innovation policies. China, Canada, USA, Finland, Korea and Japan are created national technology foresights at various stages of shaping their own innovation policies²⁴. There were several foresight technology initiatives in Russia over the course of 1991-2013. A detailed discussion of these initiatives can be found in a monograph by IMEMO RAS²⁵.

The Skolkovo Innovation Center is the Russian state’s federal development institution to implement its own foresight. Skolkovo’s major foresight goals are:

20. http://en.wikipedia.org/wiki/Fukushima_50

21. <http://spectrum.ieee.org/slideshow/robotics/industrial-robots/meet-the-robots-of-fukushima-daiichi>

22. Gavigan, J., Scapolo, F., Keenan, M., Miles, I., Farhi, F., Lecoq, D., Capriati, M., Di Bartolomeo, T., 2001. Foresight for Regional Development Network - A Practical Guide to Regional Foresight. European Commission: Brussels.

23. http://www.innovation-policy.org.uk/share/15_Impact%20of%20Technology%20Foresight.pdf

24. Impact of Technology Foresight, NEST 2013, p.14-22 http://www.innovation-policy.org.uk/share/15_Impact%20of%20Technology%20Foresight.pdf

25. Science and Innovation: Selecting Priorities, IMEMO RAS 2012, <http://www.imemo.ru/files/File/ru/publ/2012/12042.pdf>

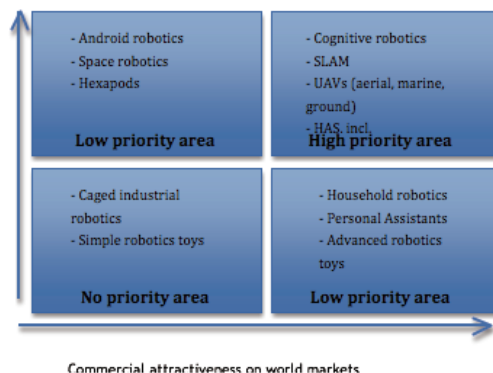
- Defining the exact priority areas of research, development and commercialization within a set of strategic priorities defined by Federal Law.
- Reaching a consensus among academics, entrepreneurs and corporate customers on what needs to be done at Skolkovo.
- Communicating these areas to all actors involved in all stages and areas of the innovation ecosystem: universities, venture capitalists, the state and corporations.
- Creating solutions in the field of robotics that are needed and sought-after, instead of solutions that may appear clever but are ultimately not in demand.

Robotics as an area of innovation support has also undergone a thorough foresight exercise involving a circle of Skolkovo experts and robotics scholars in two leading universities in the field – the Skolkovo Institute of Science and Technology (Skoltech)²⁶ and University of Innopolis²⁷. Both academic institutions have very strong ties with leading research centers in robotics: the former with MIT and the latter with Carnegie Mellon.

The results of foresight in robotics that need support from the Skolkovo Robotics Center (a subsidiary of the Innovation Center focused on robotics research and innovation) are as follows: Intelligent robotics and autonomous transport vehicles. This area is further broken down into the following priorities:

- Developing perception, cognition, autonomous navigation and planning of robotic movement in dynamic non-deterministic environments of all types (underwater, ground, aerial or space).
- New hardware or software for human-robot natural interaction, including industrial or domestic use.
- Human augmentation systems including industrial or rehabilitation exoskeletons and intelligent prosthetics.
- New hardware or software for medical robotics and surgery robotics including micro- and nano-robotics.

A major method for establishing foresights is plotting all areas of development along axes (dimensions) that reflect their desirability in the modern economy. A negative scenario is applying robotics to fields that are not in significant demand or developing solutions which has little potential for lasting technological superiority due to lack of innovation. This approach (from negative to positive) allows us to construct a BCG-matrix which has two axes: X for commercial attractiveness (on worldwide scale) and Y for technological competitive advantage or newness (sometimes called innovation potential). This matrix can be found below, with some robotics technology and product applications evaluated along these dimensions. The upper right quadrant is an area of focus for SRC – technologies which are both new and commercially attractive should be fostered with special care.



26. <http://www.skoltech.ru>

27. <http://university.innopolis.ru>

This approach allows SRC to define three areas of focus:

- High priority. Technology or product that requires focused support from SRC. These technologies and products have very high potential to be 'next big thing' in robotics.
- Low priority. These technologies or products might have niche success along with some limited novelty. Household robotics, for example, is not likely to yield much scientific innovation but, considering scale, could have significant commercial impact.
- No priority. SRC should refrain from supporting technologies in these areas. These technologies or products are mostly today mainstream robotics like industrial manipulators with minimal human interfaces, limited to very few operations and caged inside factories.

Russia: Too many roboticists, not enough robots

According to a prominent Russian educational portal, there are 30 universities that offer 'robotics and mechatronics' engineering majors for undergraduate students²⁸, with Moscow and St. Petersburg hosting more than one-third of them. Even though there is no exact data on how many bachelors come out of these faculties each year, it is fair to say that in Russia's two biggest cities, each university produces at least 30 graduates annually (the average number of students in faculty in technical universities), adding up to a total of 400. Numbers for the rest of the country might be lower, with each university producing less than half the number of graduates as Moscow and St. Petersburg. The total number for regional universities might be around 255. So, the overall Russian robotics army of engineers adds up to at least 655 graduates per year. If we add electrical and mechanical engineering majors, which are very similar to robotics and mechatronics, the number could double.



Figure 3. Map of Russian universities that offer 'robotics and mechatronics' as an engineering major

- more than five universities with robotics per region
- from two to five universities with robotics per region
- one university with robotics per region

28. http://www.moeobrazovanie.ru/specialities_vuz/mehatronika_i_robototehnika.html

Rich history of robotics in Russia

Russia has rich history of scientific research and development in robotics. Two examples attest to this: The first military robots were introduced into Red Army service long before World War II. The world record trip made along an extraterrestrial surface belonged to Russian Lunokhod-2 for more than 40 years before Nasa's Opportunity Rover beat it in 2014. These achievements would not have been possible without world-class scientific schools of robotics, mechatronics, energy supplies and artificial intelligence. From the available data, there are over 120 private companies and government-funded research centers in Russia with strong interdisciplinary competences in these fields. Major locations for robotics research and development in Russia are Moscow, St. Petersburg, Ryazan, Kovrov, Tomsk, Taganrog, Vladivostok and Magnitogorsk.

Robot density in Russia

The International Federation of Robotics has devised and constantly updates very important indicator of robotics development in the world – robot density. The official definition of robot density is the number of multipurpose industrial robots per 10,000 persons employed in manufacturing²⁹. Figure 4 shows robot density in selected countries. It is clear that the leading country, South Korea, has more than 200 times the robot density of Russia. Such a humble indicator of robotics activity is attributable to the state of Russian manufacturing, which has been in dramatic decline for the last 25 years.

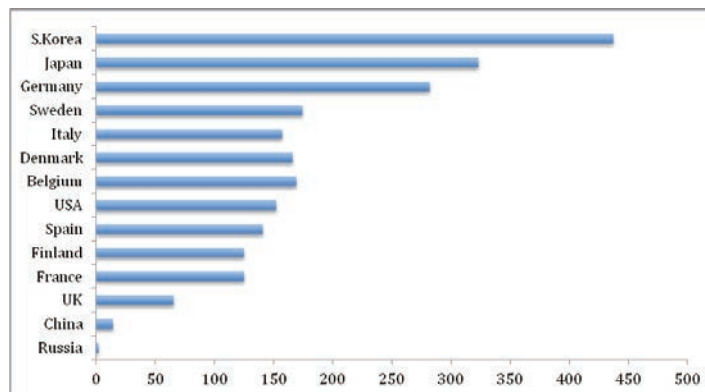


Figure 4. Robot Density in Selected Countries

These two contrasting factors – the very high number of graduates proficient in robotics and the very low robot density – reveal the depths of hidden opportunity in the Russian market. There is booming demand in all kinds of robotics, which requires a skilled workforce. Russia is the only country in the world with this huge asymmetry in between robotics graduates and robot density. Russian roboticists are capable of creating solutions for all manner of robotics - not only for local but also international markets.

Skolkovo Robotics Center as a center of Civil Robotics Competences

As stated above, the development of robotics from scientific proposal to industry-graded product requires

29. Industrial Robotics. International Federation of Robotics 2014. www.ifr.org

hard work, competent people, patience, the right infrastructure and capital.

Skolkovo is a leading Russian federal development institution which is granted exclusive powers to help innovative teams negotiate the 'death valley' of startups. Skolkovo focuses on five sectors:

Nuclear, Biomed, Energy, Space and ICT. All five fields (or clusters) are physically located at the Skolkovo Innovation Center: People work at Skolkovo Technopark and live in the surrounding accommodation. This approach is not new – the Soviet Union successfully created a few dozen science cities all over its territory. What distinguishes the modern approach is pulling together all the key elements of a successful innovation ecosystem: a world-class research and education facility in the Skolkovo Science and Technology Institute (Skoltech), key partners like Cisco, IBM, Panasonic.

In 2013-2014 Skolkovo consolidated almost all of Russia's civilian robotics projects in a hub for catapulting startups from prototype to commercial products - the Skolkovo Robotics Center (SRC). It is the primary center for interdisciplinary research and was decreed as separate organization unit in August 2014 with four employees. SRC's mission is fourfold:

- to support Russia's re-industrialization with the creation of a high-tech robotics industry;
- to raise awareness nationally and globally about Skolkovo, Skoltech and Russian robotics research and startups;
- to attract thought leaders and resources to support the emerging Russian robotics industry;
- to accelerate the growth of Russian robotics by creating opportunities for new and existing companies.

SRC aims to be a major center of civilian robotics in Russia, bringing together under the Skolkovo brand all commercially viable enterprises working in the field of robotics. In order to achieve that goal, SRC is pursuing a number of projects:

- Creating the first Russian hackspace designated specifically for robotics projects. Skolkovo hackspace is not only a fablab (laboratory), but also a place where co-working means co-roboting;
- Creating a mentors/experts network in robotics for startup acceleration programs;
- Creating a network of research centers to facilitate knowledge-exchange;
- Creating a stream of robotics competitions to facilitate the selection of the most promising teams.

Skolkovo Robotics Center has over 35 robotics startups (as of May 2015). Table 2 shows a list of selected projects specified according to the field of application: industrial, service and components:

Project name	Short description	City of origin	Segment (industrial, service or components)	Commercial status	Year of market entry
VisionLabs	Smart camera - compact multifunction device with built-in computer vision algorithms for solving a wide range of tasks.	Moscow	Components	On market	--
Webot	Webot is a telepresence robot and a set of Internet services. High-definition telepresence technology was developed for Webot.	Moscow	Service	On market	--

xTurion	Autonomous navigation technology embodied in a mobile robot for the protection and monitoring of residential and office space. Robot "is" all-sky cameras and sensors	St. Petersburg	Service	In development	2017
Nanosemantix Lab	The project aims to create SAAS solutions for online stores and retail, which allows on-site service "one stop" service for users of applications.	Moscow	Service	On market	--
Lexy	Lexy is an intelligent assistant, desktop device with artificial intelligence and full voice interface. Lexy is the only such device that can work without an Internet connection.	Moscow	Service	In development	2017
INTELLECTUAL ROBOT HYPERBOK	The main idea of the «Hyberbok» project is to create an affordable and intellectual home robot oriented at a wide range of customers.	Moscow	Service	In development	2018
NaviRobot	The development of a commercial web-platform for connecting personal robots and "smart" appliances and providing their users with additional online services for the operator's business model, well-proven in the telecommunications market.	Moscow	Service	In development	2018
SyboTech	The main product of the project - software RNS, designed to meet the challenges of mobile robots navigating indoors.	Moscow	Components	On market	--
Transist Video	Navigating with video for unmanned UAVs from the air, auxiliary to the GPS / GLONASS and inertial navigation.	Moscow	Components	In development	2020

ExoAtlet	An exoskeleton that aids rehabilitation and social integration for people with impaired motor function of the lower limbs.	Moscow	Service	In development	2017
Vist Mining Technology	ACS mining transportation complexes on the basis of GLONASS technologies and robotic systems of technological processes of open cast mining "Intelligent careers". Automates the process of transportation, excavation, drilling and blast mining without direct human intervention	Moscow	industrial	On market	--
Aurora	Development of robotic platform with open-source software interface for development of UGV control systems.	Ryazan	Components, Service	On market	--
TRIK	Educational robotics solution for professional educators and hobbyists. Built on a unique controller TRIK, which is functionally superior to counterparts in the price segment of the mass market (voice and video recognition on board).	St. Petersburg	Service	On market	--
Future Laboratory	Drone for automated diagnostic overhead high-voltage power lines, which allows companies to perform complex but inexpensive repair of power grid.	Ekaterinburg	Industrial	In development	2016

Le Talo	Drone-as-a-service. The project is aimed at solving the problem of traffic jams due to an accident. Using multi-copter to obtain the position of vehicles at an accident, allowing the driver to quickly release the roadway and wait for clearance at the side of the accident or on the stationary traffic police post. Development objective: the creation of a cloud service to provide services drones.	Vladimir	Service	In development	2016
SMP Robotics	The development of autonomous motion control system for ground robot for security and surveillance. Equipped with a panoramic surveillance system, the robot is able to perform automatic patrols of the protected area and intended to replace the patrolling guard.	Zelenograd	Service	On market	--
GNOM-ROV	Small underwater tele-operated surveillance robot. Major application – visual observation of marine ships and constructions with depth of up to 400 m.	Moscow	Service	On market	--

Table 2. List of selected Skolkovo Robotics startups

Skolkovo Robotics Center competences

Based on the robotics foresight mentioned above and an analysis of projects involved with Skolkovo Robotics, it is possible to form a list of general high-level competences of teams with SRC:

- Industrial and service robotics:

Research and development of software and hardware for Intelligent Transportation Systems, including automation of transport logistics operations.

- Marine robotics including underwater robotics:

Research and development of unmanned underwater robots for service and inspection.

- Navigation and SLAM:

Research and development of autopilots and tools of autonomous navigation for indoor, outdoor, marine and air applications.

- Machine vision systems:

Research and development of hardware and software for machine vision systems to the customer's request

- Educational Robotics Solutions:

Research and development of hardware and software for STEM robotics education.

- Medical Robotics:

Research and development in microsurgery and rehabilitation robotics including sophisticated mechatronics and micromechanics.

- Intelligent user interfaces:

Research and development of software and hardware for natural language user interfaces: speech, gestures, BCI, haptic.

Where to create the next Robotics Center

As stated and explored above, robotics is important in all types of discussions: academic, public and commercial. However, the only place robots are commonplace is auto-manufacturing plants. We can see countries with very high levels of robot density (the number of robots per 10,000 employees in industry) but with very few incentives to do any research and commercialization in robotics. In other words, being a country with a high level of robots in industry and high level of robotics research are two different things. The obvious example is the US, which has very weak industrial robotics but very strong research in service robotics. In order to start an academic discourse on how to set up a robotics center, we have designed some guidelines that should be considered as a prerequisite in creating a robotics center and its infrastructure.

Guideline	Description
Talent	An abundance of talented graduate engineers with backgrounds in robotics and mechanical engineering is a key propriety for a robotics center
Customers	Established links to the offices of potential customers of robotics
Interdisciplinary teams	The ability for teams to reach out to experts in various disciplines (computer science, design and even psychology)
Venture Capital	Access to venture capitalists capable of supplying smart and patient capital
Infrastructure	Cheap lab/office rent, space to set up meetings and conferences
Experts, mentors and acceleration	Access to a wide network of experts for evaluation, acceleration and mentorship programs
Geography	Proximity to centers of fundamental and applied research in robotics
Services	Cheap and reliable services for prototyping
Financial support	Robotics is yet not very attractive to investors. Government financial support is necessary to attract venture capital for robotics projects.

Table 3. Guidelines of a typical robotics centers

These guidelines advise policy makers on whether robotics center can be launched in the particular state or area. Without such a preliminary evaluation, setting up a successful, lasting robotics center is problematic.

Conclusion

Skolkovo's approach to fostering startups and an entire ecosystem is inherently multidisciplinary, and thereafter its focus on robotics is natural consequence. Russia has a long history of technological advances with outstanding robotics achievements (yet mostly in space and military). Hundreds of young graduates add to the army of Russian roboticists every year. Beside the low level of robot density in Russia, the country's high talent capacity creates the capability to excel in robotics, if only the state creates opportunity for that young generations of engineers to set up new startups. Then experienced mentors, advisors and capitalists lead these entrepreneurs through 'death valley', en route to commercial success. SRC is employing all of Russia's inherited capabilities to gather all viable civilian robotics startups in one hub to share common knowledge and resources. Connections between technology, industry and community is done through this vast and powerful network. Skolkovo Robotics Center facilitates networking with online and offline tools. The unique experience of creating a robotics center results in guidelines that are rigid but adapt to the times and circumstances of a given project. Some current estimation for guidelines are presented in this paper.

List of abbreviations

AV	Autonomous Vehicle
BCI	Brain Computer Interface
GPT	General Purpose Technology
HAS	Human Augmentation Systems
IR	Intelligent Robotics
SLAM	Simultaneous Location And Mapping
SRC	Skolkovo Robotics Center
STEM	Science Technology Engineering Mathematics
UAV	Unmanned Autonomous Vehicle
UGV	Unmanned Ground Vehicle