

# The Fablabization of Russia: MISiS and Skoltech Experiences in Digital Fabrication and Rapid Prototyping

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Digital fabrication is the core of a system that reveals the importance of experiential learning and making things with one's own hands and ideas. Neil Gershenfeld, Director of MIT's Center for Bits and Atoms (CBA), and leader of the international fab lab movement, is bringing a revolution to every individual by working to allow them "to design and produce tangible objects on demand, wherever and whenever they need them. Widespread access to these technologies will challenge traditional models of business, aid, and education." In this paper we will explore a set of digital fabrication activities that are centered in Russia but also have links to the European network of Fab Labs. The discussion of these activities in this paper focuses on educational and community-based efforts using interviews from some of the primary people in this network. Currently there is great interest in digital fabrication in Russia and the beginnings of a fab lab network are already forming there. These new efforts join a growing network of labs in Europe and around the globe. The first lab in Russia was established at 1502 MPEI High School in Moscow from 2009-2011. The next lab was established at MISiS, the National University of Science and Technology. This university-level lab is directed by Associate Professor Vladimir Kuznetsov with the support of Vice Rector Tim O'Connor and members of the Fab Lab Network at the CBA. Following in the footsteps of the MISiS lab is an effort getting underway at Skolkovo Institute of Science and Technology (Skoltech) based in Skolkovo, outside of Moscow. Skoltech is a new university under construction and is currently designing its lab under the guidance of Mats Hanson, Ilia Dubinsky, and Brendan Smith.

## **Keywords**

digital fabrication, rapid prototyping, fab lab, experiential learning, maker education, Russia, MISiS, Skoltech, CDIO, innovation, entrepreneurship

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Digital fabrication is the core of a system that reveals the importance of experiential learning and making things with one's own hands and ideas. Neil Gershenfeld, Director of MIT's Center for Bits and Atoms (CBA), and leader of the international fab lab movement, is bringing a revolution to every individual by working to allow them "to design and produce tangible objects on demand, wherever and whenever they need them. Widespread access to these technologies will challenge traditional models of business, aid, and education."<sup>1</sup> In this paper we will explore a set of digital fabrication activities that are centered in Russia but also have links to the European network of Fab Labs. The discussion of these activities in this paper focuses on educational and community-based efforts using interviews from some of the primary people in this network.

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<sup>1</sup> How To Make Almost Anything, Foreign Affairs Essay December 2012

Both the MISiS lab and the Skoltech lab are designed for use in educational activities. Each school is endorsing and implementing a hands-on aspect to science, technology, and engineering education. The Skoltech mission is “to educate students, advance knowledge, and foster innovation in order to address critical scientific, technological, and innovation challenges and gaps facing Russia and the world.” Both schools are working to imbue students with more knowledge and skills in innovation and entrepreneurship, and to encourage them to pursue careers that will enhance and add value to the societal and economic futures of Russia and the world.

This paper will detail the experience that these two labs have had in their activities getting started in Russia and look further afield to see how these experiences might be beneficial to labs starting other parts of Europe. The story contains anecdotes about how things were achieved and what obstacles were overcome. A key contribution from the interviewed subjects is their discussion of why they believe the Fab labs are vital to their cities and countries. Additionally the authors will highlight the importance of the maker experience, digital learning, experiential learning and the CDIO movement. Interviews or quotes from Vladimir Kuznetsov, Edward Crawley, Mats Hanson, Ed Seidel, and others will provide vital perspectives and insights into aspects of the fab lab value structure, experiential learning, and new initiatives in education.

### **1<sup>st</sup> in Russia: Fablab @ School**

In 2009, The Fab Network made its first inroads into Russia with the Fablab@School project, Experimentarium, at the 1502 MPEI high school in Moscow. The project was

financed by Euan Baird, former CEO of Schlumberger, and executed in partnership with Stanford and MIT. The lab finished construction and officially opened in June 2011, and now is “a state-of-the-art digital fabrication lab bringing hands-on education to youth in Russia”. Students have used projects made in the lab to compete in and win multiple international prizes at events such as the Russian Baltic Science and Technology Competition, Junior Moscow Engineer and Physics Institute, and the Moscow Open Conference of Natural Science Potential, among others.

The project continues to be successful, and it was a great first step that generated a lot of media attention about digital fabrication in Russia, and spurred on many of the other larger projects that are mentioned later in this paper.

### **Trailblazers: The Fablab @ NUST MISiS**

On October 7<sup>th</sup>, 2008, the President of Russia issued a decree creating a network of elite “National Research Universities”, identifying specialized skill areas for leading universities and officially recognizing those core competencies. The Moscow Institute of Steel and Alloys (hereafter NUST MISiS), was one of the first two universities recognized, and with a diverse set of skills and competencies, received the distinguished title of “National University of Science and Technology”, empowered to lead and excel in all areas of science, technology, engineering, and mathematics (STEM).

In 2011, the then-Rector of NUST MISiS, Dmitry Livanov, who had the reputation as “the most innovative rector in Russia”, was driving the modernization of the university forward in a number of different areas. The Federal Agency of Youth Affairs (RosMolodyozh) had identified the digital fabrication and rapid prototyping ideas of the Center for Bits and Atoms (CBA) at MIT as very forward-thinking and innovative concepts that they wanted to bring to Russia to help develop youth in a positive direction, but first they needed a flagship implementation in Russia to convince all of the skeptics. They contacted Rector Livanov at NUST MISiS and he fully supported the idea of bringing another Fablab in Russia to his university, and put Vice-Rector Tim O’Connor and Associate Professor Vladimir Kuznetsov in charge of the project, with a dedicated budget. Livanov also engaged with Ivan Bortnik, the Executive Director of the Association of Innovative Regions of Russia (AIRR), and they decided to contribute fifty percent of the financial resources that supported the eventual development of the MISiS Fablab.

At the time, Kuznetsov was already assembling an innovative prototyping lab at MISiS known as “CAD2Part”, and had purchased a Flexicam CNC machine, some HAAS 3-axis and 5-axis milling machines, and some other equipment, to outfit the facility. When the directive came down from Livanov, he quickly changed gears, and began to collaborate closely with Neil Gershenfeld, Sherry Lassiter, and the rest of the CBA team at the Media Lab. The project also received backing from the Russian Venture Company. On April 20,

2012, the lab was inaugurated, although equipment continued to arrive and be set up for several months.

During the summer of 2012, Sherry Lassiter and a team of students from CBA came to the MISiS lab to provide technical support and training for 7-10 days. In October 2012, the MISiS Fablab was featured in a special 1-day event as part of the Open Innovations Forum.

The lab continued to develop into 2013 as the MISiS Fablab began a push to implement Fablab 2.0 ideas in its lab. Fablab 1.0 was the the idea of being able to make anything with a relatively inexpensive set of commercially available machines. Fablab 2.0 takes that idea even further by trying to replace even the standard Fablab machines by new machines that are made by the Fablab users themselves. Fablab 2.0 has the potential to eventually make most Fablab 1.0 commercial equipment obsolete.

The MISiS group started by creating their own prototype of the “MTM (Machines That Make) Snap” Milling Machine. During summer 2013 they redesigned the machine to be more powerful and structurally sound, substituting bolt interfaces for snap junctions, as one example. They plan to meet or exceed all of the technical performance specifications of the workhorse MDX-20 “Modela” Milling Machine common to Fablabs.

The next step in this process is the organization of the MISiS Fablab 1.5 Conference, to be held from October 14-19, 2013 in Moscow to celebrate the exciting transition from Version 1.0 to 2.0. International experts in rapid prototyping and digital fabrication, including Neil Gershenfeld, will attend the conference and give presentations, seminars, and workshops.

Among the challenges that he has faced and overcome in the first year of operation, lab manager Vladimir Kuznetsov describes the early problems of equipment sourcing. Specific to the Russian context, Kuznetsov had to re-think the traditional Fablab supply chain network based on the standard parts list. Many of those items are simply not available in the Russian Federation, and import/export efforts would be too costly and time-consuming. In many cases, Kuznetsov switched to German and Taiwanese suppliers instead of American ones, for a better supply and maintenance support infrastructure for his facility. That is also a contributing factor to Kuznetsov's wholehearted adoption of Fablab 2.0 ideas, which would move all Fablab's off of the industrial machine manufacturer supply chain network, if fully realized.

### **Expansion to All-Russia Network of Centers for Youth Innovative Creativity**

In May 2012, after the initial success of the MISiS Fablab in collaboration with MIT CBA, the Ministry of Economic Development and the Association of Innovative Regions of Russia jointly announced a new network of digital fabrication facilities for the nation, as they attempted to implement a top-down "fablabization" of the Russian Federation.

The facilities will be known as ‘Centers for Youth Innovative Creativity’, and will be targeted towards school-age children older than 10 years old. These labs will foster an innovative, creative spirit in young adults, and steer them towards positive choices as they grow and develop.

An open call for proposals was announced and final winners were selected by the end of the 2012, with financing levels announced for calendar year 2013. Both the sheer quantity of labs selected and the wide geographic range were staggering. The development teams across Russia have moved aggressively with the funding that they have received to launch websites and grand opening ceremonies announcing their presence in the Russian digital fabrication ecosystem. 30-40 new Centers for Youth Innovative Creativity have already opened by August 2013.

<b>FAST FACTS: NEW CENTERS FOR YOUTH INNOVATIVE CREATIVITY (2013)</b>	
Number of new centers	53
Number of new centers in Moscow	21
Number of oblasts (regions) represented	13
Total Federal Budget Allocated (USD)	4.34 million
Total Sum of Regional Budgets Allocated (USD)	1.8 million

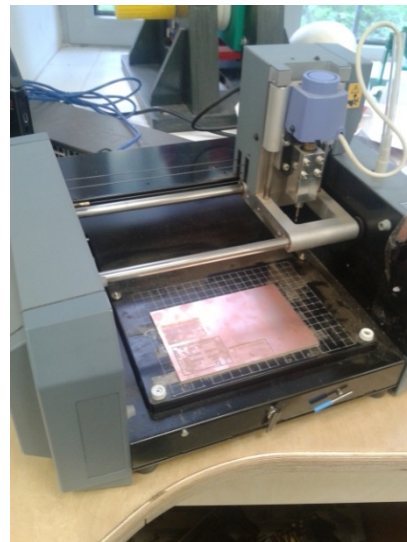
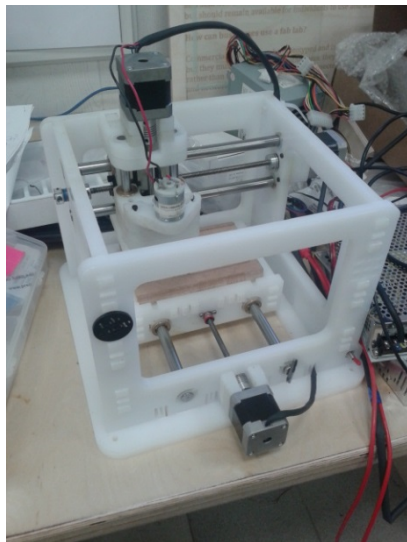
**Table 1: Centers for Youth Innovative Creativity, 2013 Statistics**

The Centers for Youth Innovative Creativity initiative is a great boost for the Fab Community in Russia, providing a great source for numerous new Fablabs in the near future. NUST MISiS is planning to hold Fab Camps in its facility in August 2013 in order to train the teams from Belgorod, Astrakhan, and Kemerovo, and then report their progress to the greater Fab Community at the Fab9Japan Conference in Yokohama, Japan from August 20-27, 2013.

### **Stories from the 1<sup>st</sup> Year of Operation at MISiS**

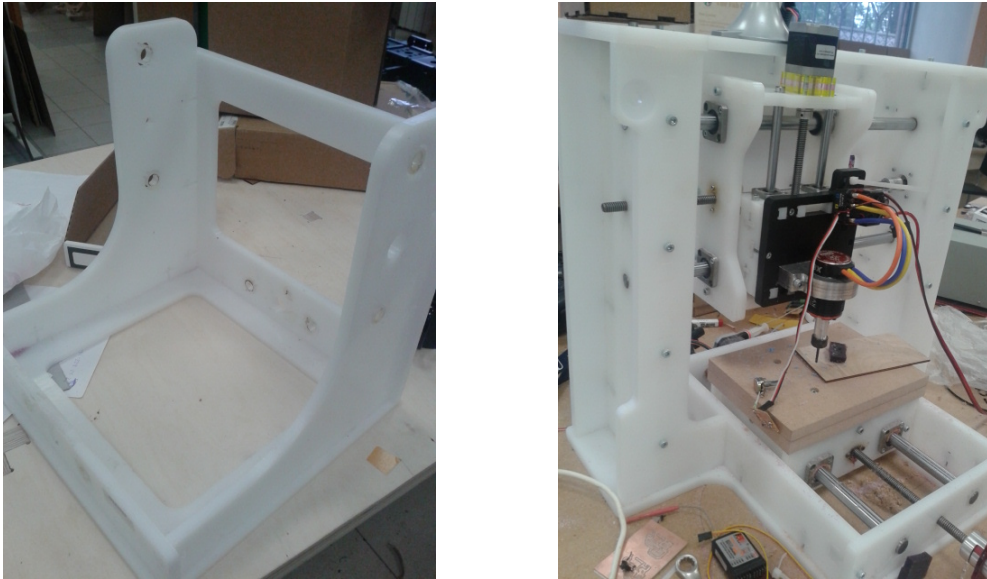
#### **Version 2.0 Modela**

In 2013 the MISiS Fablab decided to begin the implementation of Fablab 2.0 concepts, and went about it in a systematic fashion. Their first step was to carbon copy the existing design published by MIT CBA personnel, the MTM Snap milling machine. The MISiS Fablab personnel began with that task, shown in the figure below.



**Figure 1: (Left) MTM Snap milling machine made at MISiS Fablab;  
(Right) Roland MDX-20 Modela milling machine at MISiS Fablab**

The NUST MISiS team analyzed the MTM Snap design and realized that the working area was significant smaller than that of the commercially available Modela machine. In addition it was lacking in several other parameters. They decided to ambitiously design a Fablab 2.0 milling machine that meets or exceeds the Modela in all relevant performance characteristics.



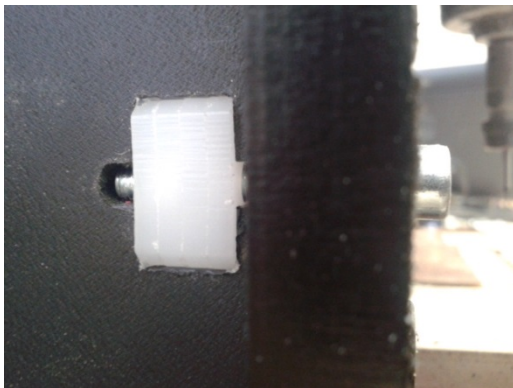
**Figure 2: (Left) 1<sup>st</sup> prototype of larger and more structurally-sound plastic frame;  
(Right) 2<sup>nd</sup> prototype, completed and functional**

They redesigned the machine to be bigger and more structurally robust, switch from “snap” mechanical interfaces to press fit pin-joints, and bolt interfaces. The bolt interface went through a re-design, as a machined and tapped metal nut-plate was replaced by a “nut-adapter”, conceptualized in the NUST MISiS Fablab, and easily made on the CNC Router. It consists of a small block of plastic cut out at the same time as the rest of the plastic structure, with several drilling and recessing steps done in advance so

that a standard M5 nut will rest securely inside. The evolution of this mechanical interface is displayed in the figures below.



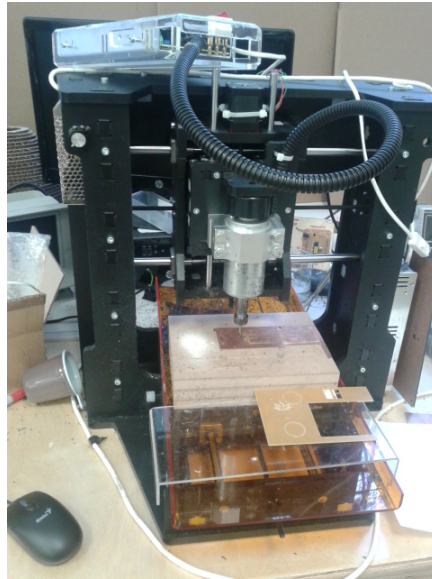
**Figure 3: (Left) Original “Snap” junction;  
(Right) Re-designed bolt interface with metal nut-plate**



**Figure 4: (Left) Re-designed bolt interface with plastic “nut-adapter” installed;  
(Right) “Nut adapter” shown exposed with M5 nut**

At that point the team ran into a supply chain issue, unable to resupply the white HDPE plastic sheets imported from the Czech Republic as fast as was needed. The team located a Russian HDPE supplier, but with black HDPE sheets that had a loose thickness tolerance. The Czech supplier had a precise 12mm thickness on all their sheets. However the thickness of the Russian HDPE varied from 11.6 to 11.9 mm throughout.

Realizing that the critical dimensions of the design were built around 12mm, which bounded the possible variations of the Russian supplier, the team pushed ahead and built the same machine to print, with the new material, shown in the figure below.



**Figure 5: Black HDPE plastic prototype of Fablab 2.0 milling machine**

The new prototype functioned very well, with only several small drawbacks. In the figures below, one can see how the precise 12mm press fit interfaces now have small gaps introduced due to the new thickness dimension. However, all of those interfaces are reinforced with bolt-nut-adapter interfaces, so they are not structurally critical.



**Figure 6: (Left) Precise 12mm thick press fit interface on white HDPE plastic prototype**

**(Right) Loose 11.6-11.9mm thick interface on black HDPE plastic prototype**

With this robust, functional black HDPE plastic prototype and a reliable Russian supplier relationship set up, the next steps for the future are to redesign all of the structural elements to be makeable in the 150 x 200 mm x 50-75 mm working area of the machine, building up from smaller modular structural forms, or “digital structures”.

### **Low-cost Fablab 2.0: Skoltech Student Oleg Urzhumtsev creates “PennyBot”**

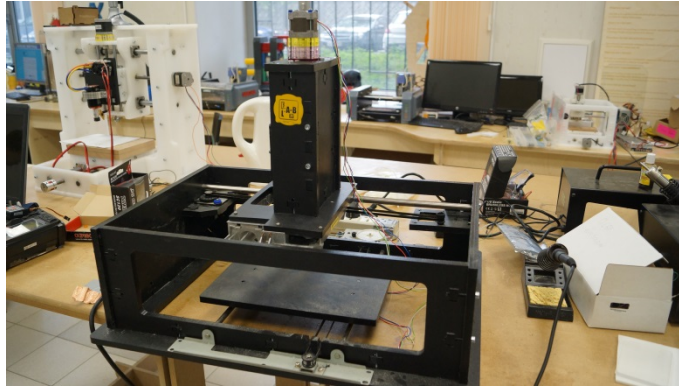
During the 2013 Skoltech summer internship in the MISiS Fablab, Oleg Urzhumtsev chose as his personal project, the task of creating a 3-axis CNC milling machine in the Fablab 2.0 model. He primarily used recycled parts from scanners and other IT equipment, and called the creation “PennyBot”, a reference to its extremely low cost.



**Figure 7: Oleg Urzhumstev, Skoltech student, with PennyBot in the MISiS Fablab**

He began the project in July 2013, and after a short cost analysis found that the most expensive parts would be the stepper motors and guides. He then realized that those components could also be found in older model scanners (such as mid-1990s flatbed SCSI scanners), as well as in some printers. Those reused components would provide enough precision, as they were built on industrial production lines. As of August 2013, he has already produced a working prototype, seen below. His next steps are to add

replaceable tooling heads, switching from a spindle to a 3D printer extruder, to a laser head.



**Figure 8: PennyBot, the low-cost Fablab 2.0 3-axis CNC milling machine made from recycled scanner parts**

### **MISiS Fablab Booth at 2013 All-Russian “Seliger” Youth Innovation Forum**

Since 2005, Lake Seliger has hosted an annual All-Russian youth forum, which gathers Russia’s young talents for innovative brainstorming. The forum has become a wonderful occasion for young innovators to meet potential partners and investors and to participate in various training sessions and workshops, as well as to learn about new ideas and share their own views on innovation.



**Figure 9: Russian Youth play with MISiS Fablab equipment in an outdoor tent**

In July 2013, the participants of the forum were introduced to the NUST MISiS Tent, — an outdoor digital fabrication lab created from equipment taken from the FabLab at the National University of Science and Technology MISiS. The NUST MISiS tent raised a great deal of interest among the participants, with different lectures and discussions being held throughout the day. It was then transformed into an open digital fabrication facility, for use by anybody willing to create an object with their own hands.



**Figure 10: Visitors to the NUST MISiS Tent test a small robot with a MISiS instructor**

The participants could test a laser machine, a vinyl cutter, a milling machine, or a 3D-printer. The only FabLab machine that was missing was a large milling machine, but everybody was able to see some objects that had been made with it – wooden arm-chairs, tables, and stools. The exposed digital fabrication machines attracted a lot of innovative folks who came to test their personal fabrication skills and the tent was full of people all day long.



**Figure 11: MISiS instructor gives a seminar in robotics and digital fabrication of electronic circuits and components**

FabLabs are open-space and open-design labs, and sadly most young Russian people do not understand fully understand this concept. However, outreach events like the Seliger Forum provide an opportunity to develop this understanding in the general population over time. The MISiS Tent introduced many young and proactive Russians to digital fabrication technology and now many of them are considering coming to Fablabs and Centers of Youth Innovative Creativity located near their homes. MISiS representatives believe that active participation in these digital fabrication facilities will teach new participants the value of open-space and open-design projects and engage a larger community in support of those ideas.

## October 2013 FABLAB 1.5 Conference – “digital fabrication: getting personal”



**Figure 12: Official information package for “FABLAB 1.5 – digital fabrication: getting personal” conference at MISiS in partnership with MIT and Skoltech**

The “FABLAB 1.5 – digital fabrication: getting personal” conference will be held at MISiS from October 14-19, 2013, in partnership with MIT and Skoltech. The focus of the conference is moving towards ‘personal digital fabrication machines’, or Fablab 2.0 machines, created by individuals, not by industrial production lines. The major topics of discussion are:

1. International network of Fablabs
2. Fablab 1.5: Transition from commercially produced machines to where machines make machines
3. Current commercial technology of digital fabrication
4. Future of digital fabrication: digital materials and assemblers

Representatives from MIT, MISiS, Skoltech, and other European Fablabs will give presentations, and the conference will also include exhibitions on Digital Materials,

Tools of Personal Fabrication, and Fab Academy. Master classes will be offered, as well as a joint working session between MIT, NUST MISiS, and Skoltech, entitled “Machines that Make Machines”.

### **Skoltech: Innovative Russian Higher Education for the 21<sup>st</sup> Century**

As one of the centerpieces of the nationwide effort of “economic modernization”, President Dmitry Medvedev announced the creation of a new innovation city, Skolkovo, located on the west side of Moscow, and home to a creative community of corporations, start-ups, research labs, and academic institutions. One of the central academic institutions of the project, Skolkovo Institute of Science and Technology, abbreviated as “Skoltech”, was inaugurated in October 2011 with MIT professor and entrepreneur/innovator Edward Crawley as its president. As the university developed around the central ideas of entrepreneurship and innovation, this idea of empowering individuals to creatively express themselves mapped very well on to the central tenets of digital fabrication and rapid prototyping. As the head of the MIT Department of Aeronautics and Astronautics in the late 1990s, Crawley created the Gelb Lab, an effective traditional and rapid prototyping facility that allowed the students to reinforce what they had learned in the lecture halls with “project-based learning”, a key component of the CDIO (Conceive-Design-Implement-Operate) curricular methodology that he helped to develop with his partners from Sweden.

In order to develop an innovative, unified curricular design for the new university, Crawley turned to his Swedish colleagues again for assistance, bringing in Kristina Edstrom and Mats Hanson from the Swedish Royal Institute of Technology (KTH). Mats Hanson, the Skoltech Dean of Education, is particularly well-versed in mechatronics and the importance of digital fabrication and rapid prototyping, with extensive experience at the Design Division and D-School at Stanford University, as well as at KTH as a professor of Mechatronics. Asked to define the difference between industrial and academic versions of rapid prototyping, Hanson said that “industrial professionals use prototyping to create products for the market; educators and students use prototyping to create products, and through that process, they create understanding.”

As Hanson led the effort to develop Skoltech’s curriculum, he recognized that digital fabrication and rapid prototyping had to be integrated from the very beginning. In one example, he spoke of “the importance of Bloom’s Taxonomy: to reinforce knowledge through cognitive, affective, and physio-motoric methods”. The ‘affective’ knowledge, where students develop self-confidence in their own ability to realize their abstract ideas into concrete prototypes, is particularly important and celebrated in the Fab community. Hanson spoke of different kinds of prototyping that he feels are important for the students to progress through, from “sketches, to mock-ups, to functional prototypes, to testing and verification of functional prototypes”. In fact, his central vision for the Skoltech rapid prototyping laboratory this is planned for development in 2013-14 is for it to be “design, prototyping, and testing (DPT)”, with a full complement

of creative design spaces and resources, as well as test equipment: load cells, tensile/compressive testing, shock/vibration, thermal vacuum chambers, required for a wide range of prototype testing. He hopes that this will distinguish the Skoltech facility from its peer laboratories, and hopefully provide some creative lessons for the overall Fab community.

According to Hanson, the development plan for rapid prototyping facilities is first to leverage the knowledge and the facilities of the Fablab at NUST-MISiS for the 2013-14 academic year, in order to build knowledge and capability within Skoltech personnel. During that same period, the first “educational lab” at Skoltech will be planned and procured. It will be located in Skolkovo in a temporary location, while the main campus is being constructed. It will be setup in summer 2014 and will begin operations in support of Skoltech educational programs in the fall 2014, continuing to serve in that role until the campus is finished, sometime in 2016.

Inside the main campus building, the research programs of the institute will be designed around 15 different CREIs (Centers for Research, Education, and Innovation). Many of these CREIs will finance supporting fabrication and prototyping facilities for laboratory needs, replacing and greatly exceeding the capabilities of the initial educational lab. In the long-term vision there will be at least 5-10 such facilities at the institute, to which students, staff, faculty members, and even outside community members can come and work on realizing their abstract ideas into functional physical forms.

### **MISiS—Skoltech Collaborative Partnership: Recent Success Stories**

Skoltech reached out to MISiS in June 2013 to start a collaborative partnership in digital fabrication and rapid prototyping in order to advance the development and proliferation of the field inside Russia. The first success story from the partnership was a Fab Camp held by MISiS for 8 Skoltech Master's students from June 24-28, 2013.



**Figure 13: Irina Zhelavskaya, a Skoltech master's student, learns how to use the laser cutter from her NUST MISiS Fablab instructor**

The students came up-to-speed on all of the primary equipment and techniques required for basic digital fabrication, in just 5 days of study and practice. Vage Taamazyan, one Skoltech participant, said about the experience, "I think that the really impressive thing about working in the Fablab is that with just a small number of machines, for example, a laser cutter, you can make anything that you want."



**Figure 14: Irina Zhelavskaya and Vage Taamazyan, Skoltech master’s students, practice electronic assembly, integration, and testing with their NUST MISiS Fablab instructor**

The Fab Camp really instilled a passion for the subject in the Skoltech students, leading 4 of them to decide to pursue a summer internship in the Fablab where they will complete advanced prototyping projects and perform some holistic analysis report and provide recommendations to the university administration about how to proceed with development of the Skoltech facility.

Internship research topics include:

1. Supply chain management and consumption control
2. Composition of minimum viable Fablab
3. Implementation of Fablab 2.0 methods
4. Implementation of Digital Materials technologies

Oleg Urzhumtsev spoke of his excitement about this collaboration and future ones, “When we have our own laboratory, we will be able to invite students from other

universities to come there and work together with us, to exchange our experiences, and develop the overall community of young scientists and engineers.”

The Fab Camp and summer internship have been supported at the highest levels of both Skoltech and NUST MISiS administration. Skoltech Senior Vice President for Innovation and Research, Ed Seidel, visited the Fab Camp and stated that “Skoltech and MISiS have a lot in common. I feel that this is one of the best institutes, with whom we need to work together, develop joint programs, and also educational and research laboratories. The opportunities for long-term partnership are many.” He continued, “Often while you studying at your university you study an enormous amount of theory and just a small amount of time is devoted to practice. However, thanks to opportunities like the projects of CDIO and Fablab, there is a chance to see the tangible result of one’s own learning. It is possible to construct functional prototypes and control them, and to perform this work in collaborative teams. I think certainly this area will be one more area of partnership between Skoltech and MISiS.”

The Skoltech students will assist with the organization and execution of the MISiS Fablab Version 1.5 Conference as well as perform project work in the lab throughout the 2013-14 academic year.

Several practical “application periods” from Skoltech curricular elements will be carried out in the MISiS Fablab in order to reinforce more theoretical concepts from the classroom lectures.

Next year when Skoltech’s educational lab is established, the two facilities will work in close collaboration to provide a gold standard of excellence for digital fabrication and rapid prototyping in the Russian context. They will also invite organizations from across the nation to visit Moscow and participate in training and collaborative work sessions, in order to accomplish the goal set out by presidential decree: The Fablablization of Russia.

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Notes from interviews gathered in Moscow in 2013 were used. Brendan Smith conducted and reported on these interviews.