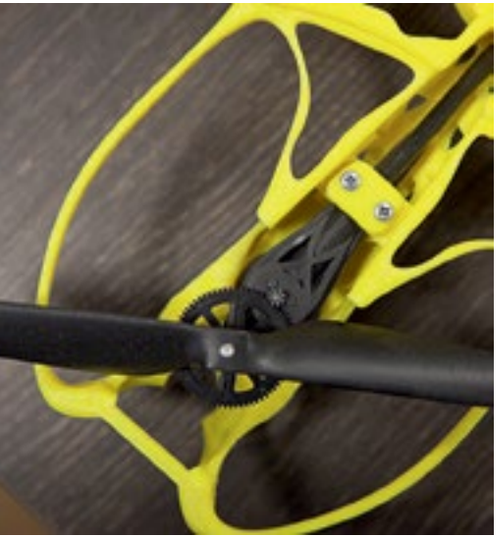
Beyond Intuition

PROFESSOR ALEXEY BOROVKOV OF THE PETER THE GREAT POLYTECHNIC UNIVERSITY IN ST. PETERSBURG DESCRIBES HOW *FACTORIES OF THE FUTURE* ARE NOW BEING SHAPED.

Arkady SOSNOV. Photos: Timur Turgunov, the Archive of the CompMechLab® Engineering Centre at St. Petersburg Polytechnic University, the Press Centre of the *Young Professionals* Agency of Strategic Initiatives



Alexey Ivanovich Borovkov has a plethora of appointments, each of which would suffice as a full-time occupation: Pro-Rector for Long-Term Projects at St. Petersburg Polytechnic University, Senior Adviser to the Institute of Advanced Production Technologies, Manager of the *5-100* University Programme, Professor in the Mechanics and Control Processes Department, Leader and Co-Director of the *Technet* Working Group (a cross-branch project of the National Technological Initiative — NTI), Member of a Working Group of the Russian President's Economic Council on the Digital Economy, Head of the *Factories of the Future* Design Office in St. Petersburg, and finally Director of the CompMechLab® Engineering Centre at St. Petersburg Polytechnic University, which provides services to companies in various branches of industry — the motor industry, aviation, shipbuilding, oil production... This versatility is down to the fact that this is the only *computer* engineering centre in the country using full-scale digital models with a high degree of relevance to actual objects and processes (*smart models*).

Professor Borovkov has been informally described as a specialist in solving insoluble problems. Who is involved in the production of cars with unique characteristics for the President of Russia? Borovkov's team. Who was able to ensure the efficiency of the main circulation pumps' operating wheels at the Tianwan Nuclear Power Station in China for the next forty years? Once again, the engineers in Borovkov's team. The list goes on...

The CompMechLab® has proved its international competitiveness by working with leading international corporations — not just on individual projects but on a regular basis, tuning into their technological circuits. Just as importantly, the Engineering Centre is involved in the transfer of technologies at the same level, taking

The articles are supported by a St. Petersburg grant

Investment in Intellect

world trends into account, carrying out Scientific Research and Experimental Design for leading Russian companies, including in the energy, shipbuilding and aviation industries.

As long ago as 1987 Alexey Borovkov founded Russia's first computer engineering laboratory — ten years earlier than a similar structure appeared in Moscow University. It was that laboratory that became the conceptual, creative and personnel base of the Computer Engineering Centre at St. Petersburg Polytechnic University. Looking back a few more years, he graduated from what was probably the most progressive faculty in the university — the Physics-Mechanics Faculty, founded by the legendary Abram Ioffe and Stepan Timoshenko (who subsequently made Stanford University in the USA famous), where the Deputy Dean was Pyotr Kapitsa, who went on to found the Physical-Technical Institute in Moscow. It is symbolic: today Borovkov, an alumnus of the Soviet scientific-technical school, has become a visionary extending the horizons of the new digital economy.

— Alexey Ivanovich, you are one of those people who not only look to the future of our economy but are bringing that future closer. In these uncertain times for the economy how realistic is it to be planning factories for 2035?

— The first thing I would say is that the National Technological Initiative was launched by the President of Russia in December 2014 and is now one of the priorities of government policy. It is a long-term all-embracing programme to guarantee the global competitiveness of our economy until 2035. How can it be guaranteed? Besides the gradual development of enterprises and companies, we have to direct our energies towards future markets — mainly the so-called *nets* (network-based markets): *Aeronet*, for example — distributors for pilotless aircraft, *Avtonet* — the driverless car market, *Marinet* — the market for marine intellectual systems on and under the water.

The articles are supported by a St. Petersburg grant

A conversation to the point. Academician of the Russian Academy of Sciences Andrey Rudskoy, Rector of the Peter the Great Polytechnic University in St. Petersburg, Professor Alexey Borovkov and Nikolay Tsukanov, Plenipotentiary Representative of the President of the Russian Federation in the Northwest Federal District, in the Polytechnic University's Engineering Centre. At the computer — Leading Engineer Ivan Stebenev.

The most extensive of them is *Technet*, aimed at the development and use of advanced production technologies. This is, above all, digital planning and design, the creation and use of new materials (I would particularly mention metamaterials and composition materials), additive technologies (that market is growing at approximately 30% per year, at a time when the standard market is growing by only 5–7%), total automation and robotization of manufacturing.

Then, of course, there are *Big Data*: industrial robots will report on themselves and interact with one another. There is now an *Internet of Things*, or an industrial Internet — streams of data which have to be collated, structured, analyzed and used, i.e. controlled. For example, a supermodern gas turbine generates 500 terabytes of informative data every twenty-four hours and that information has to be used both for controlling the operation of the turbine and for making new generations of turbines. The *Internet of Things* is developing in almost everything around us, in all the gadgets we use. Smart homes and smart cities will come whether we want them or not.

The necessity of *Big Data* analysis is to stimulate the development of predictive analysis and digital design, and for that high-performance capacities are needed. The Polytechnic University has one of the most powerful supercomputers in the country, aimed specifically at use in industry.

Factories of the Future are bringing together everything I have mentioned and generating new-generation specialists with the necessary competences. In *Factories of the Future* it will all come as a package: planning, design, analysis and distribution in a digital format. Digital transformation is no longer a fashionable trend but an urgent necessity and the current reality of modern hi-tech production.

Some people think *Factories of the Future* is an attractive image, a meme, but in actual fact they are an integral element of the 4th Industrial Revolution that is now happening — a structural link and, I would say, the quintessence of the digital transformation of the economy.

— A key project of the Polytechnic University and its Engineering Centre is *Cortege* — the development of a range of presidential-class cars. To what extent have you used digital technologies in this project?

— This project has actually served as an example of the 'solution of insoluble problems' on the basis of digital technologies, not only in the motor industry. In 2014 the task of making four

The articles are supported by a St. Petersburg grant

cars on a single modular platform was announced: the Russian motor industry replied that it was impossible to make them within the allotted time. We, in conjunction with the Central Scientific Research Automobile and Automotive Engine Institute, managed to do it and the result was confirmed in June 2016 on an independent testing area in Berlin: at the very first attempt the sedan was given the highest mark in passive safety. What led to this success? A unique ecosystem of technologies, a digital platform and a team of engineers with world-class competences who are ready to use them at any moment, to work with any company interested in change.

The question arose as to whether this approach could be extended to other branches of industry. And shortly afterwards, at the Forum for Strategic Initiatives attended by the President of Russia, we were offered the megaproject *Factories of the Future*. It was confirmed and is undoubtedly serving as a spur to the development of all sectors of the economy. In the motor industry, for instance, in about two years' time we will be close to the creation of open digital platforms providing new opportunities for small and medium businesses, including in the regions, to become part of the process of producing their own cars.

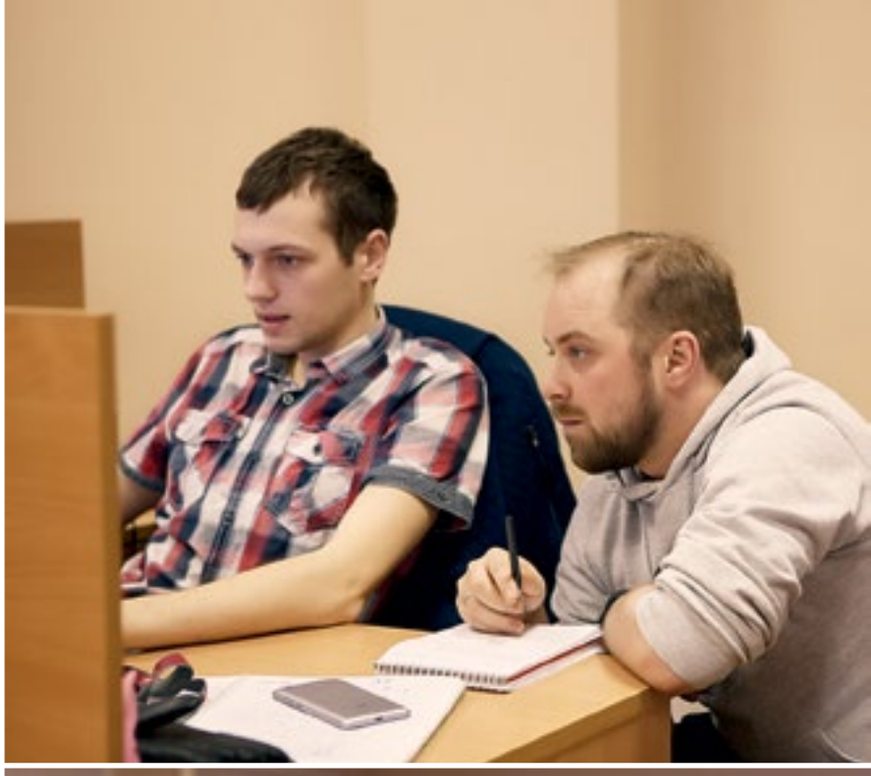
Professor Alexey Borovkov presents the *Factories of the Future* project to President Putin at the Forum of Strategic Initiatives. Moscow, 21 July 2016.

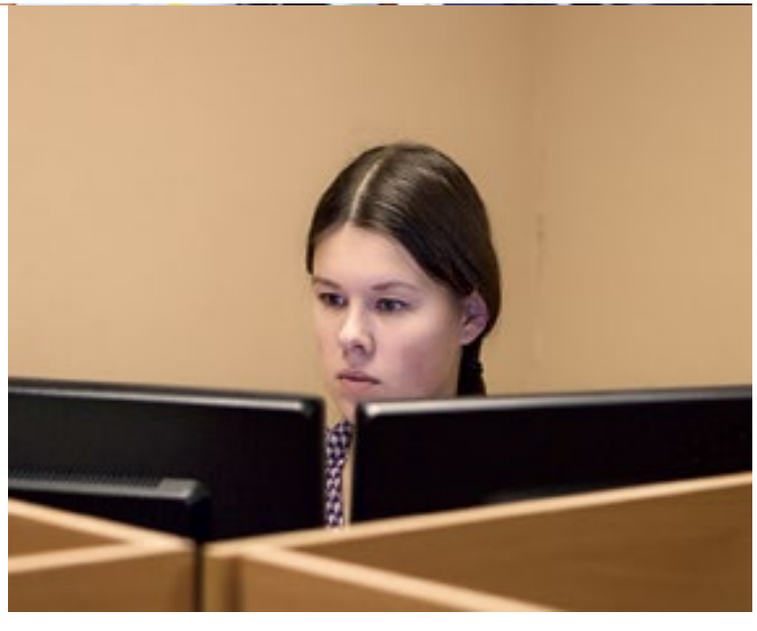
— Is it possible to speak of a particular road for the Russian economy? How tempting it would be to avoid all the ruts and potholes at the side of the road and set off down the wide highway of scientific-technical progress...

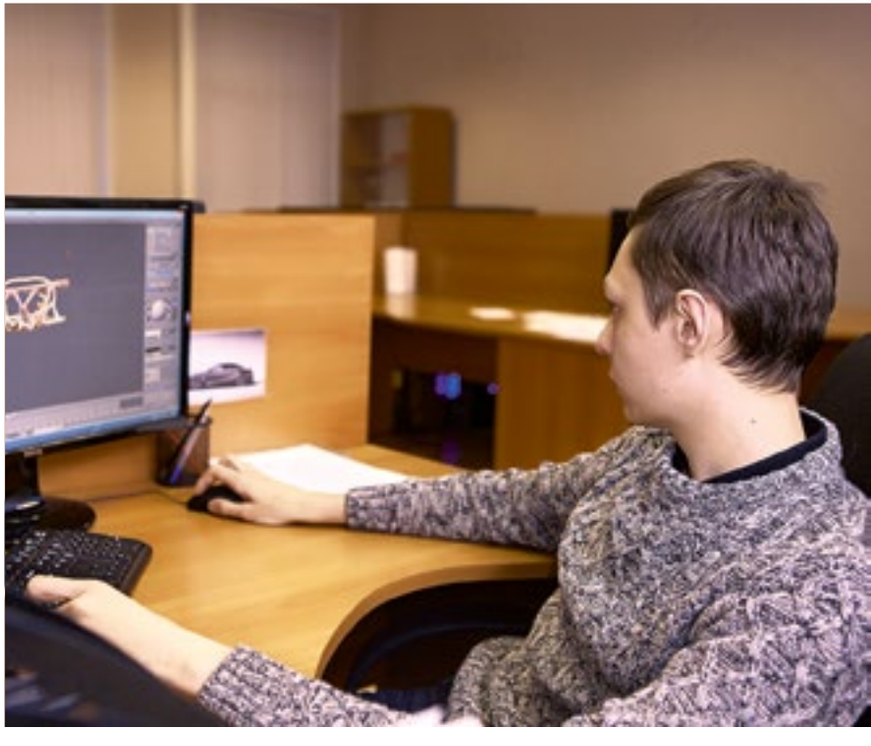
— We do not have the right to isolate ourselves from the dynamic processes of world development. With such an approach the country would inevitably start to grow weaker, and then we would not be able to speak about any defence capability nor about the greatness of Russia.

There is an expression which German Gref brought back from Silicon Valley: when we are just preparing to discuss something over lunch, the Chinese have already been doing it since morning. However, it should be taken into account that Russia is extremely creative. Russia is one great design bureau: we know how to design, but we do not know how to be really competitive in mass production. The Fourth Industrial Revolution will enable us to add value in areas where we are strong and offset our weaknesses: by using advanced production technologies and the business model of *Factories of the Future* we will be able partly to exclude the human factor in production, draw up distribution networks of certified suppliers, reserving the right to expertise in digital planning and design, i.e. key competencies. It will be a fundamentally different economy.

The articles are supported by a St. Petersburg grant







The principle of educating students in the Institute of Advanced Production Technologies is gradual immersion in real projects. In other words, studying by means of actual Scientific Research and Experimental Design projects.

— What is the role of universities in building the economy of the future?

— Going over to a digital economy will require a different class of specialists — that is a challenge for universities, as the traditional cycle for the training of specialists is 5 or 6 years. It is obviously necessary to solve a whole range of problems in education, research and development: to set up applied graduate studies by carrying out actual Scientific Research and Experimental Design projects, to run topical problem-orientated projects, to develop key competencies in universities' engineering centres, centres of competency and engineering companies. It is important to set up a digital ecosystem as an infrastructure — to create virtual experimental testing-grounds as centres for the assembly, testing and efficient use of advanced multidisciplinary and cross-branch computer technologies. And, of course, the main task is the formation of world-class competencies. The slogan 'Competent personnel decide everything' has never been as relevant as it is now.

At the Polytechnic University we are already running a training programme for new-generation specialists via the Institute of Advanced Production Technologies. These *engineering special forces*, as our Rector Andrey Rudskoy calls them, will create knowledge-intensive products adapted as closely as possible to the demands of the market and specific consumers. A university-type experimental testing-ground is being created on the basis of the Polytechnic University's Institute of Advanced Production Technologies — as a prototype and generator of digital factories for various branches of the hi-tech industry.

Our *5-100* programme is aimed at the integration of Russian higher education establishments into the international educational arena and guaranteeing their competitiveness. In autumn 2016 the priority project *The Contemporary Digital Education Environment in the Russian Federation* was approved with the aim of creating the infrastructure, standards and legislative basis for high-quality and accessible online education. The colleges and universities in this project integrate into the international scientific education arena, act as centres of innovation and should operate in close contact with business in the concept of continuous education.

Oleg Bocharov, Deputy Minister of Trade and Industry, holding a bracket for the aerospace industry, optimized in accordance with the principles of bionic design.

— And is the Fab Lab also part of the economy of the future?

— The Fab Lab is another story, aimed at the development of creativity. Unfortunately it is outside the ambit of what is required by the hi-tech industry. It is all very well and interesting, but the solutions they come up with cannot, as a rule, be applied. It is a sort of island of enthusiasts who want to create and communicate with one another, which is great, generally speaking.

The articles are supported by a St. Petersburg grant

The customized electric CML-CAR, being developed in the Engineering Centre.

— It is now 2017, but when the Internet markets take over the world economy, which is what the National Technological Initiative is aimed at, it will be 2035. So the people who will be at the most mature age then are now 18–20, but you have to make the choice here and now. How do you pick out the creators of the digital economy before sending them to the frontier of technology?

— It is a long and painstaking process. We do not strive for mass inclusion but for the minimization of random choice — the search for motivated students who realize that learning will not be easy. As before we start the process almost while they are still at school, but in earnest when they are in the third year at university. The technologies of the world's leading companies become more knowledge-intensive and multidisciplinary year by year, and the specialist of the future will need engineering, aerodynamics, heat and mass transfer, materials science and electromagnetism, all underpinned by maths and physics. Of course many of them want to design the best cars in the world, but experience has shown that only one in ten is suitable, and only one in twenty has the necessary knowledge, mentality, competences and the ability to work without mistakes. Incidentally, thanks to the Unified National Exam youngsters from all regions of Russia now have the chance to join the new economy — over 60% of our students are from other cities.

So, from the third year onwards we select the best, follow their progress and appoint them a tutor (a qualified working engineer, not a professor) to whom they can apply at virtually any time. This very quickly helps to remove barriers of misunderstanding and save unnecessary stress, and the young person gradually becomes involved in real projects and finds a job. The structure of education is changing fundamentally. It is now 50% formalized knowledge (lectures and seminars) and 50% informal knowledge obtained in the course of a real project working alongside experts.

The main stimulus for the development of *engineering special forces* is interesting tasks — very interesting ones. Sometimes, even when he joins a global oil and gas company, a specialist after a while begins to realize that he has reached the limit of his development and will not develop further in the next 15–20 years. And so he comes back to us — for a salary comparable with the international level for employees, but also for the most interesting tasks and various Scientific Research and Experimental Design projects.

The articles are supported by a St. Petersburg grant

— And are there plenty of tasks? After all, we are not all living in 2035 as you are...

— There certainly are: the number of complex tasks is increasing, as is the queue of customers — not only Russian customers, but Russia too is expanding with the NTI and the *Factories of the Future*. Industry is manufacturing new products and cannot do without advanced technologies as it is faced with complex problems that are already beyond the bounds of intuition. A developer does not understand how to take into account the mutual influence of different components in the operating process. Previously expensive field studies came to the rescue. Today there is not the finance or infrastructure for such experiments, but any design can now be calculated to a high degree of accuracy and tested virtually.

— Calculated beyond the bounds of intuition?

— We obtain solutions that cannot be generated by intuition. In one of my lectures there is an illustration of this boundary: there is a solution within the limits of a head designer's intuition and there is a solution obtained by us beyond the bounds of intuition — essentially the digital twin of an actual object. Moreover, the world will learn of this solution within one, two or three years. The world's leading companies do not release such solutions on to the market immediately, since they are leaders even without them. These solutions will be released whenever there is a threat to their leadership. This is a different business model characteristic of the new digital economy. That is why it was stated at the World Economic Forum in Davos at the beginning of 2016 that only 20% of companies will survive in the new economy. And it really will be possible to join the new economy only with advanced technology, not with a slide rule.

— The search for leaders of the NTI has to encompass the whole country, and obviously primarily in universities. How is it being organized?

— The intensive financial support of leading Russian universities began in 2007. It is now 2017, and the NTI is aimed at making us the leaders in the field by 2035. There is a term *growth point*. It is deplorable if these points remain points from year to year, from programme to programme. It is my profound conviction that after ten years of substantial support of leading universities these points ought to have grown and become expanses of growth. In some areas this has happened: science and science education centres of international standard have been established

The Polytechnic University and the Engineering Centre signed a collaboration agreement with the group of companies for the creation of a *Factory of the Future* for space technology. The university's engineers have been involved in rocket and aircraft building for quite a long time. Under the *Factories of the Future* megaproject, in conjunction with leading specialists from this industry, they have succeeded in selecting urgent industrial and corporate problems-challenges which can be solved with the aid of digital twins.

The articles are supported by a St. Petersburg grant

Maxim MEIKSIN, Chairman of the St. Petersburg Committee on Industrial Policy and Innovations:

— We want to see a St. Petersburg that is not only beautiful and cultural but also a hi-tech city. As soon as the NTI was introduced Governor Georgy Poltavchenko supported the initiative and we approved a programme under which we will be opening a new engineering centre of a specific type every year as accelerators of industrial development. We have already opened a centre for the synthesis of active pharmaceutical substances and an engineering centre for cyber-security for the IT industry is about to open. Our plans for the next two years are engineering centres for radio-electronics in 2018 and for photonics in 2019.

Education is the second important segment. NTI Olympiads have started to be held in schools and the teenage generation are more and more actively embracing the logic of the digital economy. Interesting trends are appearing in St. Petersburg more strikingly than anywhere else. In recent years we have observed an active demand for engineering specialities in the hi-tech industry and increased competition in chemistry and biology. The Kirov Plant has a tradition of taking on youngsters entering a profile college as employees and this year there are nine of them competing for each job.

and forty engineering centres have been created by the collaboration between the Ministry of Education and Science and the Ministry of Trade and Industry. The purpose was to create no more than one such centre in each higher education establishment, but with installations targeting leadership in that particular area in the country and in the world. Creative spaces are springing up around them, teams of innovators are being formed and the NTI is aimed at the selection of these teams. It could be a small or medium business, or allotted hi-tech subdivisions in companies (*Greenfields*) which demonstrate the highest productivity and economic efficiency against the general background. They grow more quickly than the others, which is evident from the results of the *Business Gazelles* competition held in St. Petersburg.

There are other Russia-wide projects aimed at the search for leaders and their targeted support. The Innovation Assistance Foundation (Bortnik Foundation), a Russian venture company, is already holding competitions under the NTI. So the average approach to *sowing*, where finance is shared equally among everyone, is already a thing of the past — everyone may grow, but the majority will not withstand the competition. In fact the federal authorities are focusing attention on the leading teams on various levels, in both companies and universities. In this situation it is important that we remain at the forefront of technology, increase the export of hi-tech services and continue to work with world leaders.

— Is it with this in mind that the Polytechnic University has opened a branch in Shanghai?

— Yes, since last spring we have actively begun to establish contacts with Chinese hi-tech industries and, owing to the range of competencies of the Polytechnic University and its Engineering Centre, we have been able to form a pool of sixty companies which are prepared to work with us. We have simplified as far as possible the chain of communication with customers (bypassing Chinese universities, science parks, etc.). China is developing at such a rate that we always have to be a few steps ahead in order to maintain a balance of interests. We have opened a Higher School of Technological Entrepreneurship at the Polytechnic University with the accent on hi-tech. It will help to set up new businesses on a global scale and, in particular, to establish stable business with China, the leading world economy, so we at the Polytechnic University and the companies connected with us are interested in it in the long term. For this it is necessary to 'run forward faster than you are driven, scattering fields of intellectual know-how behind you'.

— The 20.35. The *National Technological Revolution* conference held in November in St. Petersburg summed up the year's results in the National Technological Initiative. What sort of year has it been for *Technet*?

— The first and most important event for *Technet* was the approval in February of a road map for it. Our working group has been very active: it has considered more than ten projects, mostly those of *national champions* (to use the Ministry of Economic Development's terminology) and hi-tech *business gazelles*. It is gratifying that the sparring partnership between *Technet* and *Factories of the Future* is gathering speed.

The point is that those participating in the *Factories of the Future* megaproject (and that is already around thirty substantial businesses of various types) are filling a gap that exists in the NTI — major businesses. Currently the NTI serves as a support for small and medium businesses, but we recently supported a project to create a *smart factory* based on a leading engine-building company (the cost is seven billion roubles of state and private finance).

The articles are supported by a St. Petersburg grant

At the *20.35. The National Technological Revolution* Conference. St. Petersburg, November 2017.

Photo on page 31:
The award of diplomas to master's degree students of the Insitute of Advanced Production Technologies.

Design consortia are being set up as part of the partnership between *Technet* and the *Factories of the Future* project. This trend has been noted in car production, aircraft building, helicopter building, engine building, shipbuilding and so on. An innovative ecosystem of small businesses in receipt of support from the Bortnik Foundation is beginning to form around major companies. It should be noted that *Technet* has one of the leading coefficients of the efficient use of company funds: 80% of them go towards achieving the targets specified in the road map. The innovations that are being created immediately become part of the concept of virtual factories, i.e. some of the hi-tech services, competencies and equipment can be replicated and upscaled.

— We are cutting corners, in the words of one of the speakers at the conference, in striving towards 2035, but foreign corporations are also not marking time. How can we avoid being left standing by their leap forward?

— I noticed that just this August the key term the Fourth Industrial Revolution — a digital twin — appeared on the curve of advanced technologies drawn by the Gartner analytic company. There is a sense that in the last ten years the world's leading companies have been employing diversionary tactics: they have launched fashionable trends like the industrial Internet, robotics, cyber-physical systems (all these are useful but auxiliary initiatives) and have 'forgotten' to say that for ten years they have been intensifying the creation of digital twins — both of actual objects and of actual production. Imagine a field of competition in which half the business of one of the players is 'concealed' in digital twins, which 'lie in ambush' and can 'spring out' into actual production at any moment. An invisible fundamental change is taking place in industry. Whoever generates digital twins that are relevant to real objects in the whole life cycle will dominate in tomorrow's world.

— And are there digital twins in the Polytechnic University's Engineering Centre?

— We are creating them in conjunction with companies — the world leaders in recent years. They are actually *21st century superweapons* which have to be used sensibly. A twin can be complete, i.e. almost fully adequate for an actual object and/or actual production, and then it can travel along the life cycle at the leader's pace.

The articles are supported by a St. Petersburg grant

Alexey Borovkov. Thinking Aloud

One of the problems of engineering education is that lecturers in senior courses at higher educational establishments have not worked in industry in the last 10–20 years or have never worked in industry.

According to European statistics only six per cent of the innovations proposed by technological entrepreneurs actually reach industry. It is more logical to take specific tasks-challenges from the hi-tech market and resolve them as our engineering centre does. That is the only way of compensating for the gap between the complexity of the task and the level of competences of the companies' personnel. And for us it is important that these tasks develop us and enable us to move forward, capitalizing on the experience.

I remember when we began our collaboration with a well-known American corporation: we worked on the task for four months, they then took three months to accept it and only after that were we paid. That was in 2000 — very strict conditions with daily monitoring and weekly reports. At that time we were already thinking in the Soviet way: if we can't finish it in time, we'll just extend the deadline for a day or two. We had to be re-educated.

As early as 2004 the U.S. Competitiveness Council launched a national programme for the manufacture of supercomputers and proclaimed that the winner in the competitive struggle would be the one who came out on top in calculations. And today the slides in presentations by world leaders feature endless, abundant calculations which guarantee the exponential growth of the economy. And what we are promised by artificial intellect is linked to the endlessly growing potential of calculations.

Global trends develop regardless of our wishes and readiness for change. There is only one criterion for evaluating a result: the competitiveness of the product on the world market.

If we do not promptly digitize the results of the on-site experiments which were conducted in the USSR for huge sums for finishing products and items and do not master virtual trials, it will be difficult to achieve great progress in, for instance, the aerospace industry. To paraphrase Newton's dictum: the achievements of our engineers are due to the fact that we are standing on the shoulders of giants.

Man has to get wiser more quickly than intellectual technical systems — that is one of the main challenges of the 21st century.

The CompMechLab® Engineering Centre at St. Petersburg Polytechnic University receives around 250 delegations a year. Some come for familiarization, some to discuss ways of collaboration, others to sign contracts.

The articles are supported by a St. Petersburg grant