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ROSATOM NEWS

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Science as a Priority

Every year Rosatom increases its investment in research and development (R&D). In 2018, Russian nuclear corporation's R&D investment reached $278 million.

The last year's performance and research trends were discussed at a scientific conference held in May. Event was attended by Rosatom's senior management, public authorities, scholars and businessmen.

Rosatom's strategy focuses on nine priority lines of research ranging from nuclear medicine to small modular reactors designs. Apart from applied studies, the company also pursues unbeaten tracks that often lead to the most rewarding discoveries and break new ground for creating fascinating technologies. The company included 131 pilot projects (out of 900 applications) into a consolidated R&D plan for 2019 following the last year's call for proposals. Rosatom will fund these projects with its own resources.

The company's target for R&D investments is set at 4.5% of its revenue, which is a benchmark for global innovative corporations.

The goal of the academic conference was to improve communications between R&D and business divisions of Rosatom in order

Facts & Figures

ROSATOM'S R&D INVESTMENTS

2017:
RUB 15.8 billion (USD 245 million)

2018:
RUB 18 billion (USD 278.5 million)

to convert inventions into an in-demand end product as smoothly as possible.

"Our task is to create a system that will ensure a perfect coordination and unity between science and business to achieve our common goal which is commercialization of new knowledge. Business and science are mutually responsible for the progress that we need so desperately and that is expected from us," Yuri Olenin, Rosatom's Deputy CEO for Innovation Management, said in his opening speech. Speaking about pilot projects, he noted that most of them had already been launched.

Each conference session was dedicated to one of Rosatom's priority lines of research. The panel discussion about the Breakthrough ("Proryv") Project was focused on the interim progress achieved on the fast reactors and back end of the nuclear fuel cycle. Vadim Lemekhov, Chief Designer of the Breakthrough Project, reported that the regulatory authorities had approved project design documents for BREST OD-300 nuclear power unit and the project was going through the licensing process.

VNIINM (Rosatom's main science institute on nuclear fuel) Deputy CEO Mikhail Skupov

outlined key advantages of the MUPN fuel (mixed uranium plutonium nitride fuel for fast breeder reactors – RN) over oxide and metallic fuels, and noted that 11 experimental MUPN fuel assemblies had passed reactor tests at Beloyarsk NPP. He also added that Rosatom was ready to present its comprehensive offer for the construction and testing of MUPN fuel, post-irradiation studies and repeated use of re-fabricated products. As announced on the VVER-related conference session, Rosatom's strategic goals also included updating VVER-TOI (VVER-1300) design and development of VVER units with spectral regulation (VVER-S) and ultra supercritical reactors (VVER-SKD).

Development of laser technologies is another research priority for Rosatom. Sergey Garanin, a member of the Russian Academy of Sciences and Director of the Institute of Laser Physics (part of the Russian Research Institute of Experimental Physics), reported on the use of Russian laser technologies in various areas, including medical and industrial applications.

Small nuclear power plants were also in the limelight. **"Our market analysis shows that the world will expand its power capacity of that kind to 20–23 GW by 2040, so we expect our market share to reach at least 20%,"** Anton Moskvin, Vice President for Business Development of Rusatom Overseas (a Rosatom Group company) said.

He also outlined benefits of small reactors, such as simple design, improved safety and reliability, transportability, low risk of emergencies, and others. According to him, Rosatom's competitive advantages in this field are extensive expertise in construction of large capacity nuclear power plants, existing reference reactors for the nuclear icebreaker and submarine fleet, knowledge

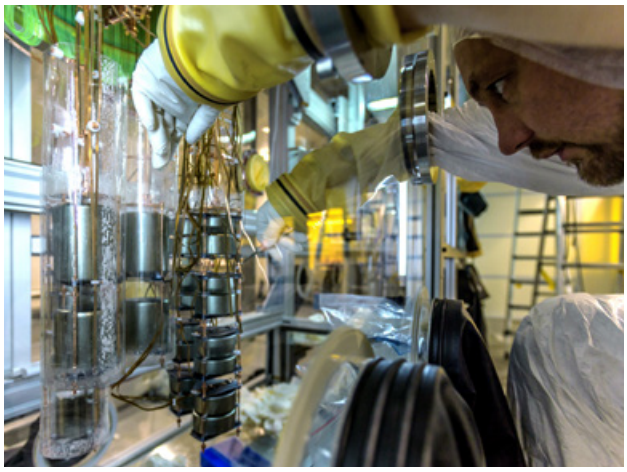
of construction and design of small nuclear power plants with a total capacity of up to 100 MW, and extensive R&D and production facilities. By now, Rosatom has completed a concept design of a two-unit plant with RITM-200 small reactors.

Conference participants touched upon nuclear medicine and Rosatom's goals in this area. As reported by Rustam Rakhmatulin, General Director of Rosatom's Izotop, the global market of radiopharmaceuticals is estimated at USD 6 billion and expected to grow at 8–12% per annum. Nuclear medicine is most widely used in diagnosis and treatment of cancer (USD 3.58 billion or 60% of the market) making it a strategic area for Rosatom.

Rusatom Healthcare's CEO Alexander Shibanov added that Rosatom had almost 70 years' expertise in manufacturing of high-end medical products. For example, the company holds 20% of the global cobalt-60 fabrication market and its range of products and services encompasses production of generators, radiopharmaceuticals, medical equipment and tools (accelerators, brachytherapeutical agents, cyclotron radiochemical facilities, monitoring equipment) and construction of health care facilities.

The conference participants were unanimous about the importance of creating new materials and technologies. Rusatom Additive Technologies' CEO Alexei Dub noted in his speech that Rosatom strived for excellence and technological advancement in many areas, including optimization of the existing reactors and fuel types, handling of cryogenic equipment, carbon and composite materials, and additive technologies. He added that innovations in the latter two areas would provide for new solutions designed to reduce product weight by 60%, reach a threefold decline of time expenditures and reduce production costs by 75%.

The conference participants also discussed advantages of spent nuclear fuel management and multi-recycling strategies, the future role of hydrogen energy and Rosatom's progress in thermonuclear and plasma research. NL



Isotopes for Science

Along with its own initiatives in nuclear research, Rosatom is an active participant in global research projects. For example, Rosatom is a major supplier of isotopes to international collaborations.

LEGEND

Neutrino physics is receiving an increasing attention. It is supposed to solve the baryon asymmetry problem, particularly why the observable universe is dominated by matter although, according to the Standard Model,

antimatter particles share the same mass as their matter counterparts.

Neutrino is expected to be identical to its antiparticle, and therefore it could be the source of baryon number violation. This theory provides for neutrinoless double beta decay, a type of radioactive process in which two neutrons transform into two protons and two electrons only, i.e. without a neutrino. The LEGEND Collaboration aims to register this process. It was established as a follow-up to the European GERDA and North American MAJORANA collaborations. A range of research institutions focused on the same experiment also support the joint team – currently the collaboration unites 50 international institutions, including 30 Russian teams. The collaboration offers a clear advantage of combining scientific and financial resources.

A laboratory in Gran Sasso, Italy, is experimenting with detectors made of highly pure germanium, which is enriched with germanium-76 isotope.

Both GERDA and MAJORANA used detectors made of germanium-76 produced at the Electrochemical Plant (ECP, a Rosatom subsidiary). ECP will supply isotopes for the new experiment but in a larger quantity. In late April, Rosatom's Izotop made a large shipment of around 20 kg of germanium-76. The collaboration aims to buy nearly 1,000 kg of isotopes soon.

LEGEND imposes very strict requirements on isotope storage and transportation. Rosatom designed a special underground interim storage facility to protect germanium-76 isotopes from cosmic radiation. Additionally, ECP created a transportation cask to maintain the same storage conditions during transportation.

AMoRE and CUPID

The Electrochemical Plant also manufactures isotopes for AMoRE, another large project focused on properties of neutrinos. The international collaboration brings together more than 100 scientists from 16 research institutions in Russia, China, Germany, South Korea, Pakistan, Thailand and Ukraine. Researchers are trying to detect neutrinoless double beta decay of another isotope, molybdenum-100. The experiment set up in an underground laboratory in Yangyang (South Korea) requires tens of kilograms of molybdenum-100.

In 2015, Rosatom's Izotop signed a contract for the supply of molybdenum-100 for the AMoRE project to South Korea by 2021, with 80 kg out of 120 kg under the contract already received.

Izotop has recently started negotiating a contract for 300 kg of molybdenum-100 from Italy's new collaboration CUPID. The collaboration designs a neutrinoless double beta decay experiment in an underground laboratory in Modane, France.

Other projects looking for neutrinoless double beta decay are being set up in the world, with other isotopes (xenon-136, selenium-82 and tellurium-130) involved. Since the Electrochemical Plant manufactures these isotopes too, talks to supply them are underway.

XMASS and WARP

Another intriguing area of physics is dark matter which, according to some scientists, accounts for a quarter of the Universe. Dark matter has not yet been observed directly despite numerous attempts, including experiments in the Large Hadron Collider and the Large Underground Xenon (LUX) experiment at the Stanford Underground Research Facility, PandaX in China, XENON100 in Italy, and experiments in the IceCube Neutrino Observatory at the South Pole. Since dark matter has not yet been detected, some researchers think we must radically revise the current model of the Universe.

Nevertheless astronomical observations of the last decades provide clear evidence that, apart from the Universe we can observe, there is also a hidden part. That is illustrated by the gravitational effects. Scientists assume that most of dark matter consists of particles with a mass of tens of giga-electronvolts, and these particles weakly interact with ordinary matter. These particles are called weakly interacting massive particles or WIMPs, and researchers are trying to trace them by their interactions.

Rosatom supplies isotopes required for the dark matter detection experiments such as

XMASS in the Kamioka underground observatory in Japan and WARP in the Gran Sasso Laboratory in Italy. NL

Izotop takes on the role of a critical link between isotope manufacturers (Rosatom's companies) and consumers within and outside Russia. Izotop supplies its products to more than 100 companies from 30 countries and more than 600 companies in Russia. The company provides a comprehensive range of professional services related to isotope sales, irradiation devices and medical equipment.

The Electrochemical Plant is a global Top-5 producer of isotopes by gas centrifugation.

The plant offers end-to-end production services – from uranium extraction and centrifugation up to production of isotope gases for commercial purposes.

The Electrochemical Plant produces 107 isotopes of 21 chemical elements and has an expertise in production of radioisotopes with a high specific activity. Its output is reaching hundreds of kilograms per year. The Electrochemical Plant supplies its products to the USA, Canada, Europe, Korea, Taiwan, China, Japan, India, Australia, Jordan, Saudi Arabia, Uzbekistan and other countries.

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Atom in the Spotlight: World News Headlines

Nuclear is discussed in leading global media on the back of growing public interest to the environmental issues increasingly more often. Here is our review of nuclear reports published in major foreign news outlets.

UK Generates Electricity from Americium

As reported by World Nuclear News (WNN), the UK's National Nuclear Laboratory (NNL) and University of Leicester converted the heat generated from americium into electricity.

The scientists lit up a small light bulb within a specially shielded area of NNL's laboratory in Cumbria, England, using heat from a small amount of americium. This tiny light is an important step towards the use of americium in radioisotope generators, which will open the way for deep space missions.

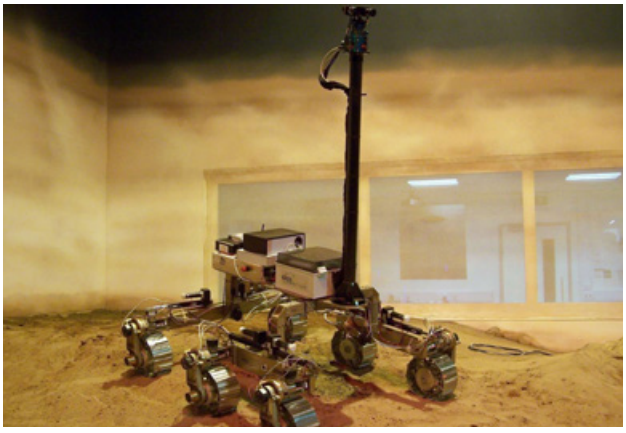
Radioisotope thermoelectric generators (RITEGs) are power batteries for space probes. Such generators use the heat produced by radioactive fuel pellets to power spacecraft on deep space missions or struggling against challenging environments on planet surfaces where other power sources such as solar panels stop functioning. With such sources of power, space probes will be able to send data and images back to the Earth for many decades.

Some existing probes use an isotope of plutonium instead, but that is in increasingly

short supply. Americium is a synthetic chemical element which does not occur naturally but is a by-product of plutonium decay. Plutonium in its turn is produced in nuclear reactors and then placed into storage with other radioactive wastes. **"It is great to think that americium can be used in this way, recycling something that is a waste from one industry into a significant asset in another,"** Tim Tinsley from the National Nuclear Laboratory (NNL) told David Nield from ScienceAlert in his interview.

"The americium in plutonium is potentially a problem for re-using the plutonium as new fuel. In extracting the americium from aged plutonium stocks, we end up with both the separated americium and also 'cleaner' plutonium – for potential re-use in the fuel cycle. So it's a win-win," NNL's researcher Adrian Bull said.

Space agencies hope to eventually make progress with high density energy sources on a series of tasks that seemed impossible a while back. **"This successful collaboration between the nuclear and space sectors has created a brand-new capability for Europe, and opens the door to a future of ambitious and exciting exploration of our solar system,"** ESA Program Lead Keith Stephenson said.



Rosatom's Russian Research Institute of Experimental Physics also conducts experiments in this field. Russian-designed RITEGs and high-energy generators use strontium-90 and plutonium-238 as radioactive isotope fuel, respectively. Last November, Rosatom supplied a set of radioisotope heater units to China for its moon exploration mission.

New Investment in Fusion

Many experts believe nuclear fusion to be an ultimate solution to the energy problem. Fusion reactors simulate reactions inside the Sun where light nuclei merging to form heavier ones releasing huge amounts of energy. On the Sun, the process is triggered by gravity. On the Earth, scientists are trying to recreate the fusion conditions with temperatures of approximately 150 million degrees. Holding plasma, which is required to fuse nuclei, is still a challenge.

Scientists have struggled since the 1930s to develop a power generation process of the future and produce spacecraft fuel using fusion.

Construction of the International Thermonuclear Experimental Reactor (ITER) began in 2010 in France. Initial estimates of its cost and completion time were changing constantly, varying from EUR 5 billion and 2016 to EUR 5 billion and 2025. It is possible that delays and political debates between the project's stakeholders will move the first trial to a later date. Not everyone agrees to wait that long.

Thermonuclear fusion attracts entrepreneurs and investors ready to finance long-term projects. **"They [science-minded**

entrepreneurs and investors] see small companies as more nimble than government-funded behemoths. They are sensitive to rising alarms over the impact of climate change. They want to create a power source with enviable possibilities: millions of times the energy potential of oil and gas and substantially more than nuclear power, without the carbon emissions of fossil fuels," Stanley Reed writes in his article for The New York Times. He talks about First Light Fusion, a British company challenging energy orthodoxy. Its founders, an Oxford University professor Yiannis Ventikos and his post-graduate student Nick Hawker, see fusion as a solution to the problem of the changing climate. At the project's start, Nick Hawker raised about USD 30 million to use a solution that differs from the ITER technology.

As a rule, fusion experiments involve extreme heating of a boiling soup of atoms known as plasma. This requires lots of energy and materials able to withstand temperatures of more than 100 million degrees. Mr. Hawker takes a different approach. He fires disc-shaped bullets the size of a dime at speeds of nearly 50,000 miles an hour at a bead of hydrogen isotopes encased in clear plastic – a fuel pellet. Upon collision, the pellet gets compressed and creates the conditions for hydrogen atoms to fuse and form helium.

First Light Fusion is a member of the Fusion Industry Association which consists of 17 private companies commercializing fusion. Among them are Tokamak Energy also located near Oxford and Commonwealth Fusion Systems founded by scientists from the Massachusetts Institute of Technology. In the article for MIT Technology Review, Leigh Phillips writes about General Fusion from Canada and California-based TAE Technologies that spent 20 years and USD 500 million to develop a fusion reactor expected to join the market in 5 years. Start-ups are not the only players on the fusion market.

Chris Mowry, CEO of General Fusion, tried to explain to MIT Technology Review why investors are interested in fusion. Leigh Phillips quotes his words, **"Fusion reactors might be harder to build, he suggests, but they are more socially acceptable. This is why there's been a rush of venture capital into fusion, he says—investors are confident there will be a sea of eager buyers waiting for whoever can make it work first."**

Meanwhile, the greens in Europe want the ITER to be closed and, as many supporters of the anti-nuclear campaign, do not see the difference between nuclear fission and fusion. **"Experts might be lining up behind nuclear, but convincing skeptical voters is something else,"** writes Leigh Phillips.

Russia with its unparalleled expertise in nuclear and thermonuclear research is one of the first participants of the ITER project and makes 9% of all project investments. Rosatom Group companies produce key reactor components and other hi-tech equipment for the ITER. **"ITER is important for us as a ground where we can test energy solutions of the future and as an opportunity to strengthen Russia's role on the global technology market,"** Rosatom's Director General Alexey Likhachev said. NL

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