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FEATURED STORIES

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Texts compiled by **Arko Olesk,** arko@tlu.ee

INTRODUCTION

From the largest structures in space to the smallest molecules in human body, this little booklet presents a selection of Estonian science. While the scope is wide, we hope that a theme emerges from many of the presented stories. This is the idea of using technology smartly to collect and analyse data, whether by monitoring Earth or humans, and to find new ways to improve the lives of people.

These articles hopefully show that Estonian science is just like Estonia itself: innovative, dynamic , smart.

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U-CAT
Turtle Robot Dives Wrecks

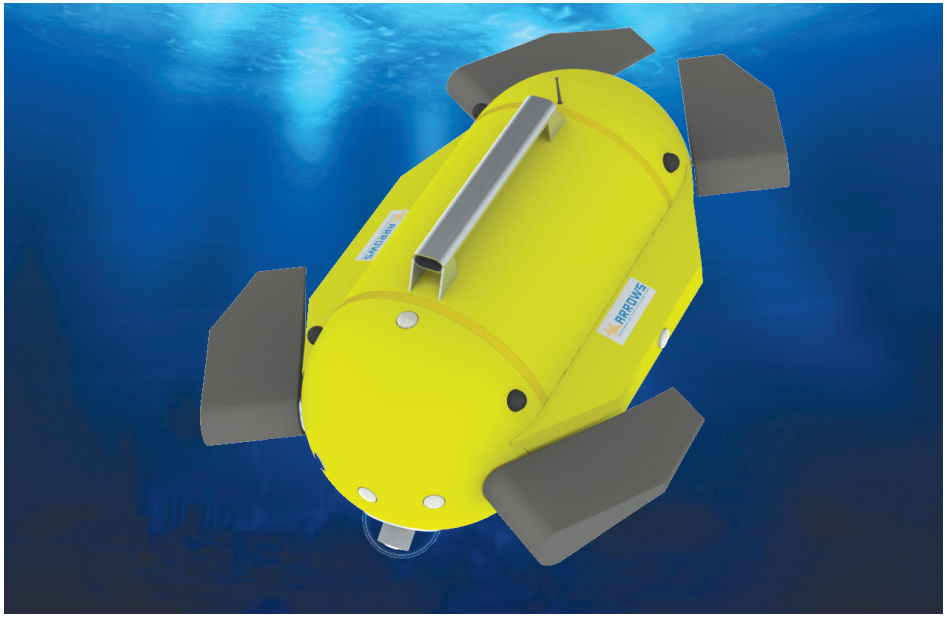
It's quiet, agile and trained to inspect shipwrecks. It can swim underwater forward and backward, up and down and turn on spot in all directions. It looks like a turtle and moves like a turtle but its belly is full of electronics: meet the Underwater Curious Archeology Turtle, short: U-CAT.

The cute yellow-faced turtle was born in Centre for Biorobotics at Tallinn University of Technology. The robot's similarity with a sea turtle is not accidental as researchers in Tallinn firmly believe that nature has already created the best designs for many solutions.

«The so called biomimetic robots – robots based on animals and plants – is an increasing trend in robotics where we try to overcome the technological bottlenecks by looking at alternative technical solutions provided by nature,» explains Maarja Kruusmaa, Head of Centre for Biorobotics.

For underwater robots, the bottleneck is the size and propulsion of the current systems. Mostly used by oil and gas industry, these are big and moved by propellers that make noise and stir water. This makes them unsuitable for more delicate tasks such as exploring shipwrecks.

This is why Kruusmaa and her colleagues created U-CAT. The turtle-inspired design with four independently moving flippers makes the robot highly maneuverable and it is specially designed to penetrate shipwrecks, an environment highly dangerous for human divers.



«Fin propulsors of U-CAT can drive the robot in all directions without disturbing water and beating up silt from the bottom, which would decrease visibility inside the shipwreck», says researcher Taavi Salumäe, the designer of the U-CAT concept.

ARROWS
ARCHAEOLOGICAL ROBOT SYSTEMS FOR THE WORLD'S SEAS

The robot, part of the EU-funded ARROWS project, carries an onboard camera and the video footage can be later used to reconstruct the underwater site. Next summer, the robots will receive their first practical test in the two European seas with most shipwrecks: the Mediterranean and the Baltic Sea.

Until then, the robots must share the lab's water tank with other underwater robots created by Kruusmaa's team, including robot fish equipped with sensors to mimic the lateral line.

Such autonomous marine robots, acting as mobile sensor networks, could deliver valuable detailed measurements of our oceans curretly unavailable because of limitations in traditional ship-based measurements.

For more information, please visit Estonia's stall at the ESOF exhibition and the scientific session «Robotics for next-generation ocean science» on Monday, June 23 at 9 AM in Little Carl, Dance Halls.

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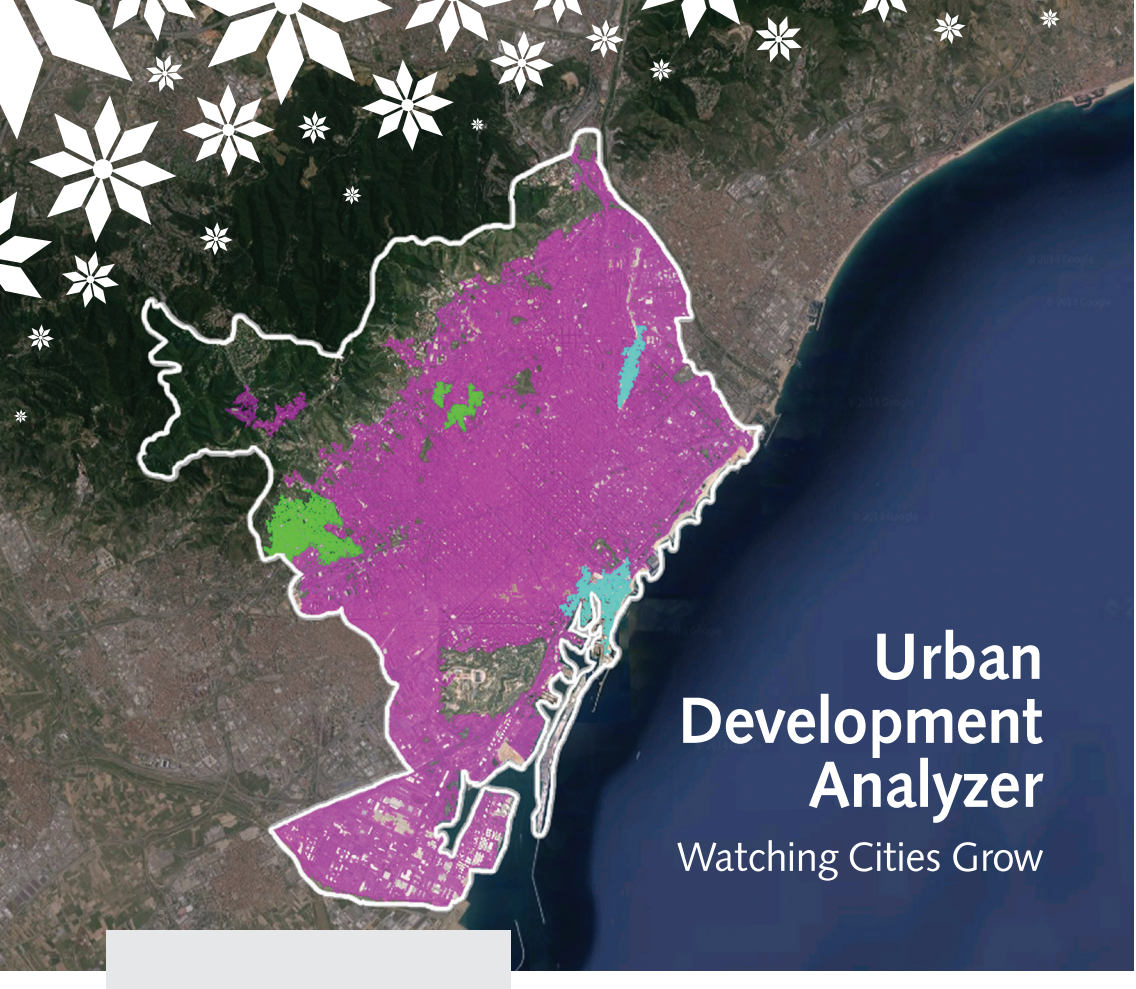

Urban Development Analyzer

Watching Cities Grow

BARCELONA, Spain
February 2010 - March 2013

- New bussiness area
- New residential area
- Previous city area

Three young Estonian scientists held their breath on April 3 this year while watching the launch of the European satellite Sentinel-1. A successful launch would mean they can start implementing their award-winning idea of mapping the growth of cities from space.

Indeed, everything went well and two weeks later the satellite beamed down its first radar images. As the satellite will soon start making continuously updated maps of the whole world, the young Estonians will use these to create pilot maps of Estonian capital Tallinn,

Barcelona in Catalonia and Milton Keynes in UK. The idea behind their application CUDA (Copernicus Urban Development Analyzer) is to combine the radar images with data about mobile phones use to follow the trends of urbanization.

Both layers of information will be presented as a visual web map that city planners and other organizations can use to track how cities grow and change. The radar images, updated every two weeks or so, will show what and where is being built, and mobile phone information reflects the patterns in the movement of people.

«When we have detailed information about the number of houses and residents in a certain area we can forecast trends how the city will develop in the future,» says Kaupo Voormansik, head of the team and physicist at Tartu Observatory. «This enables to plan the cities wiser so that there is less pollution and traffic jams.»

«There are cities in Asia and Africa that grow up to 10 per cent each year, making it difficult for local authorities to assess the actual situation,» Voormansik adds. In such areas, he says, the web map could replace housing and population registers.

With their Urban Analyzer virtual map, Voormansik and his colleagues Karlis Zalite and Kalev Koppel won the DLR Environmental Challenge at the Copernicus Masters competition last year in Germany. The competition was aimed to encourage applications for the fleet of European environmental monitoring satellites collectively known as Copernicus. The satellites provide freely accessible data

but it is up to ground teams to come up with the best ways to use it, whether for public good or commercial purposes.

Estonian companies and research organizations are already tapping into this resource. For example, Voormansik and his colleagues have already mapped flood-prone areas and assessed the extent of forest logging and land cover change in Estonia which in turn can be used to calculate the CO2-balance of the country.

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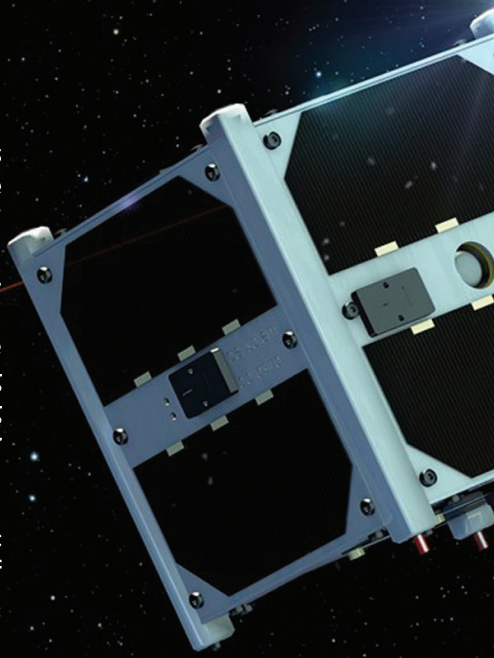
EstCube-1
The Tiny Space Revolutionist

EstCube-1, the first Estonian satellite launched last year, is much like Estonia itself – it looks deceivingly tiny but holds ideas that can change the world.



The cube that made Estonia a space nation isn't particularly big. It measures 10 centimetres on all sides and has a volume of 1 litre. Yet, the months on orbit have demonstrated its actual weight, whether by making beautiful snapshots of the Earth or simply by working almost flawlessly in the harsh conditions of the outer space.

Soon, the satellite will start fulfilling its main scientific aim by carefully unwinding a 10-metre long piece of extra-thin wire. Such wires, albeit much longer ones, may start driving space ships faster than ever before.

The novel approach, devised by Finnish scientist Pekka Janhunen, is called electric solar sail. The mission of EstCube-1 on which dozens of students from different Estonian universities have been working on for the last six years, is to conduct the first practical space test of the technology.

Electric solar sail – or e-sail – works very much like a ship sail on Earth but instead of real wind it catches charged particles coming from the Sun, and sail cloth is replaced by an electric field created by the wires. Since

there is no air resistance in space, any ship with solar sails is able to gather speed to the point that sending a space ship from Earth to other stars several light years away will become feasible.

«EstCube proves that we are able to develop new technologies independently and as innovatively as big space nations do,» says Mart Noorma, the leader of the student satellite project and the vice dean for studies at Tartu University's Faculty of Science and Technology.

With EstCube-1, Estonia is aiming to be on the forefront on several space revolutions. The electric solar sail could become a useful tool for several emerging space technologies, from clearing the orbits from space debris to mining the asteroids.

Also, the team behind EstCube expects nanosatellites – satellites with the mass up to 10 kg – to be the trend of the future, making space accessible to a wider range of users. The small and cheap satellites could do remote sensing, conduct science experiments or help with communications. Having designed and built their satellite from scratch, the Estonian students now have several start-up companies, offering hardware and software solutions suitable for nanosatellites.

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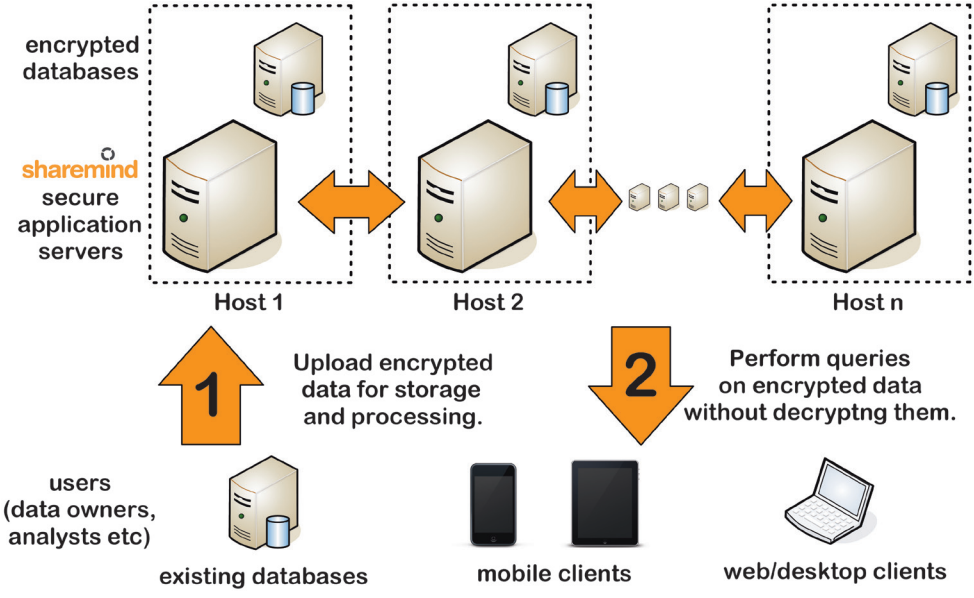
ESTCUBE
per solem ad astra

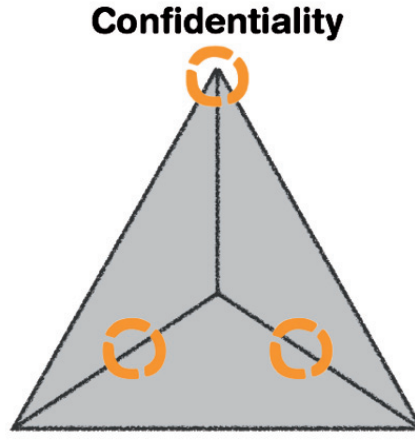
SHAREMIND
Shared, Yet Still Secret

«We wish to create a world where no-one should be afraid to share their data,» says computer scientist Dan Bogdanov, a scientist at the Estonian company Cybernetica. He is the creator of the data processing system Sharemind that allows to make computations with any data without compromising its privacy. «Basically, the system can process encrypted data,» he says.

His approach, called secure multi-party computation with secret sharing, aims to solve a common problem in data analysis. The integration of data from different sources is complicated because the relevant organizations are reluctant to share information. For very right reasons, Bogdanov emphasizes, especially when the data contains delicate personal details such as health or tax records.

With his approach, this hurdle can be overcome. «We wish to achieve the situation where sharing data does not mean giving them away,» he explains. «So far the problem has been that parties wish to maintain strict control over their data. We offer a solution that helps to make more detailed analysis without anyone having to give up control.»





«Parties are not giving away their data but share it instead, so that no-one will see the data,» says Bogdanov who earned his PhD from Tartu University for creating Sharemind. «The system will hide the content of the data by breaking it into pieces. We can make computations with the pieces and get correct results without being able to derive the original value from any piece alone.»

The system has been used by companies for compiling confidential financial reports and to analyze public sector incomes on the cloud. Cybernetica has also demonstrated how it can be used by the satellite industry to prevent satellite crashes by calculating the probablity of collisions without asking satellite owners to reveal the trajectories of individual satellites. The team has also proposed to use the system in the international sharing of people's genetic information to develop new diagnostics and drugs.

But Bogdanov is eager to see the system to be used in public sector as well. Working for Cybernetica, the company behind many of Estonia's e-systems such a digital signature, e-voting and other e-services, he would like to see that the government starts to use the system routinely to evaluate the need for and results of specific policy actions.

«Besides enabling better public policy decisions this would be another opportunity for Estonia to be a global pioneer in e-services,» he says.

Watch: http://vimeo.com/63275377

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sharemind

CAN PLANTS INFLUENCE THE CLIMATE?

"The role of the plants in this world has been greatly underestimated," says Ülo Niinemets, professor at Estonian University of Life Sciences. He is the world leading expert in studying the volatile organic compounds emitted by plants and is now asking: is there a link between climate and volatile released by the plants?

When plants get stressed – by drought or during a parasite attack, for example – they start emitting organic substances such as terpenes. These deter insects but have also be found to contribute to the production of ozone and participate in formation of aerosols and clouds. This cloud-making ability has led Niinemets to suggest that the role of plants influencing Earth's climate has been underestimated. The study of stress-emitted compounds, currently little understood, has great practical value for predicting air quality of climate change, Niinemets believes.

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THE FUN OF LEARNING SCIENCE

Margus Pedaste is convinced that students have to learn too many scientific facts and terms at school. It would be much more effective, the professor of technology education in Tartu University argues, to have students learn science by solving problems.

"We found it was really helpful, and our research found that specific support on inquiry skills, whether Web-based or involving an actual experiment in the lab, had a great effect on students' learning."

He and his colleagues have devised software programs that are able to analyse how students solve problems and support every student according to their needs. "Such learning is possible in the "smart classroom" which effectively combines people and technology," he says.

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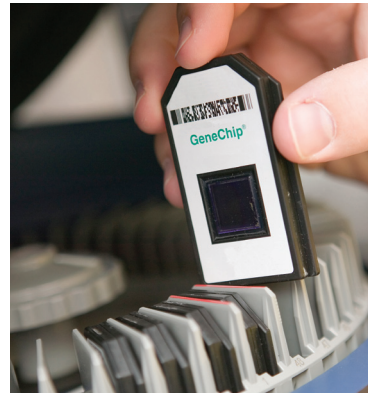
GETTING PERSONAL WITH YOUR GENES

50,000 Estonians have voluntarily donated blood to create the Estonian Biobank, a science project that has already greatly contributed to world knowledge about genes and their relation to various conditions and illnesses. But the aims of the scientist at Estonian Genome Center are much higher: everyone in Estonia aged 35 and higher should have their personal gene chip. This means the full genome sequence which would reveal any health risks and which their doctor could readily consult for any decision relating to the patient's health.

"The most important thing is that such personal approach will make people act for the benefit of their health," says professor Andres Metspalu, head of the Estonian Genome Center.



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HEARTS AND COINS

There is an electrical phenomenon – impedance – that allows us both to build better pacemakers and detect counterfeit coins. This is exactly what Mart Min, researcher at the Tallinn University of Technology has used impedance for.

Impedance, a measure of that how strongly a given material impedes travelling electricity through it - can be used to test the characteristics of many materials, both living and non-living. Min, a nominee for the European Inventor Award in 2011, has devised smarter cardiac pacemakers that can detect patients' workload and automatically adjust their heartbeat and also a device to discover counterfeit Euro coins.

His new impedance measurement technique could, in principle, be applied to all kinds of material, for example to assess the viability of organs for transplant and to monitor their functioning after the operation. "We are now discovering possible irregularities with freshly transplanted organs very early on", says the inventor.

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ALL GENETIC ROADS LEAD TO ESTONIA

Tartu, Estonia is the place to turn to when a nation gets gripped with the eternal question 'Where do we come from?'. Looking at the variation of genes, the scientists at Estonian Biocentre have traced ancient human migrations, helping to shed light on to the genetic origins of, among others, Native Americans or Aboriginal Australians.

Currently, Estonian Biocentre coordinates a consortium of some of the top labs in the field analyzing one of the biggest full genome sequences sets in the world specifically meant for doing population genetics. "One of the central questions we want to look into, and where the new complete genomes dataset comes especially handy," says Mait Metspalu, Vice Director for Research in Estonian Biocentre, "is the out of Africa migration - things were perhaps more complicated than one single and simple migration out of Africa."

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DARK BIODIVERSITY

Estonian wooded meadows are some of the most biodiverse places on Earth where dozens of different plant species have been counted on one square metre. But why are not all similar areas equally inhabitied by plant species, asks Professor Meelis Pärtel from Tartu University's Macroecology work group. To describe this, he has coined the term 'dark biodiversity'. "We can understand ecological patterns and their underlying processes better if we examine not only observed but also absent species," he explains. The knowledge about species that could be in an ecosystem but for some reason are not could provide practical tools for biodiversity conservation and invasive species control, he suggests.

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MEDICINES FROM MILK

"The number of cows whose milk can be used to produce pharmaceuticals is still very small," says Ülle Jaakma, professor of reproductive biology at Estonian University of Life Sciences. "At the same time, this technology is eagerly awaited in the pharmaceutical world. It is revolutionary since it allows making the production of medicine cheaper and more reliable."

The research group headed by Jaakma and her colleague Sulev Kõks from Tartu University is trying to contribute to this revolution. A number of Estonian cows are now waiting to give birth to cloned calves that have one extra gene in their genome. These genes allow them to milk insulin, growth hormone or other therapeutic substances once they grow up.

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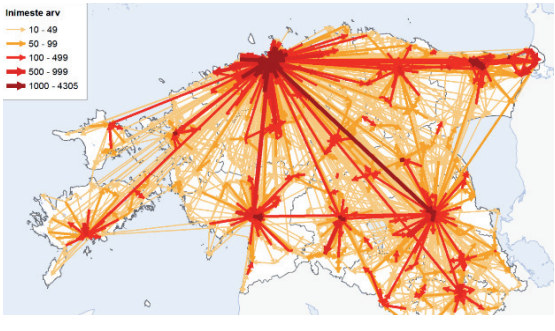
MAPPING HUMAN MOBILITY



To make smarter city planning decisions we need to examine the entire scope of everyday activities of individuals. "The old analyses often mapped "sleeping populations" using census data," says Rein Ahas, professor of human geography at University of Tartu. "The new type of analyses will put the all daily activities into studies and show the movement of people."

The making of such analysis and maps has been made easy by the fact that we all carry our mobile phone with us. Ahas and his colleagues at the Mobility Lab have developed a novel methodology based on mobile telephone use and the use active and passive mobile positioning data that allow them to investigate the mobility of people: where do people live and where do they work, where do they travel on weekends, which area of the city do they prefer during certain time of day etc. Such data allows for better environmental and city planning decision, Ahas believes.

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OIL SHALE – NATIONAL TREASURE

In Estonian we call it "põlevkivi" – "burning rock". This is oil shale, the fossil remains of primitive organisms that lived on the bottom of the sea some 450 million years ago. Today, more than 90 per cent of electricity in Estonia is produced by burning oil shale, making Estonia the only country in the world to harness this resource to such extent. And one of the few countries to have extensive scientific knowledge about oil shale: not only its use for energy and chemistry but also about its environmental impacts.

"If earlier the best use for oil shale was to produce electricity by burning it than now we know better ways to use it, for example to produce valuable shale oil or sophisticated chemical products," says Margus Pensa, research manager at Oil Shale Competence Centre, a subdivision of Tallinn University of Technology.

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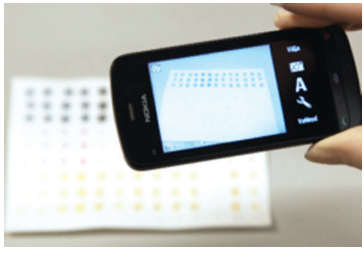
CAN CHEMISTRY BE GREEN?



Instead of running some very expensive machines, some chemical analysis could be done much more simply, quickly and cheaply, argues Mihkel Kaljurand, professor of chemistry at Tallinn University of Technology. He is one of the proponents of a new movement called green analytic chemistry. "Green stands for sustainability and less polluting,"says Kaljurand. "The amount of chemicals we use is minimal," Kaljurand says. The first practical example he and his team developed is testing wines for their content of antioxidants. A drop of wine, a drop of chemical onto it, then take a picture with your mobile phone and analyse it with a free software. "We are reviving some old methods of analysis that are based on colour change," Kaljurand explains. "But instead of looking with plain eye, now we can analyse them quantitatively with technology."

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CAPTURING THE SUN

"They say there is no sun in Estonia," says Professor Enn Mellikov. "But I always get the sun out when the investors arrive." Co-founder of the company Crystalsol, Professor Mellikov has been working on semiconductor materials development for more than 30 years. With the help of university, Crystalsol develops an entirely new type of flexible photovoltaic solar cell with a significant cost and versatility advantage compared to all currently known photovoltaic technologies. The secret? The light absorbing active layer of the solar cell is made of crystalline semiconductor particles that contain the abundant and low-cost elements copper, zinc, tin, sulphur, and selenium.

"There is no alternative to solar energy," Mellikov believes.

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UNDERSTANDING RUSSIA

"You can compare international law to a global language," says Lauri Mälksoo , professor of international law at Tartu University, "and there are several "dialects" in this international language."

Mälksoo has been studying one of those dialects that is in light of recent events in Ukraine more relevant than ever, namely, Russian. Mälksoo, the author of an upcoming book about Russia's understanding of international law, points out that Russia has emphasized the importance of international law and human rights in many instances, especially when criticizing the activity of other powers. "This indicates that international law can be a somewhat different phenomenon in different parts of the world," he says. "Russia has recently started with creating its own regional international law in Eurasia."

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THE BURIED WARRIORS

It might have been an ill-fated raid on Saaremaa or a similarly unsuccessful attempt to collect tribute. Whatever was the reason for the battle, the result were more than 40 dead bodies, buried with their ships in the south coast of the Baltic Sea island Saaremaa.

"These must have been fierce battles that already started on the sea because we have found many arrowheads," says archaeologist Jüri Peets, senior researcher at Tallinn University Institute of History who has done excavations at the Salme site. Beside weapons they have also found artefacts, such as game pawns, which indicate some of the visitors were nobleman. The discovery is significant because the fateful battle has been dated to the year 750 or before. This means almost a century before the Viking Age officially began, making the Salme ships the most important pre-Viking era find in the Baltic Sea region, if not beyond.

"There are no similar battle burials with a comparable amount of victims from that period anywhere in Europe," Peets says.

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A FERTILE APPROACH

Only one of a three fertilized eggs that reach the women's womb, will actually develop into a new human life. What determines the success of the pregnancy is, however, still mostly shrouded by mystery. Scientists at Tartu University are gaining new insights by using omics-analysis, simultaneously looking at many biological processes at work around the embryo and how they interact with each other.

"This type of work allows us to understand why in certain cases the embryo will attach to the uterus membrane and pregnancy will start and in other cases it will not," says Andres Salumets, professor or reproductive medicine at University of Tartu. For example, his team was the first in the world to map all of the genes and proteins that are activated during the moment of embryo attachment and their interaction.

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ONE MORE PINT... FOR MY GENES

The rapid transformation of Estonia in the 1990s showed Estonia as a testing ground for innovative economic and social policies. But it also made Estonia a unique laboratory to study the interaction of genes and environment. A longitudinal study led by Professor Jaanus Harro has revealed how risk behaviour such as alcohol consumption is affected by the time when young people were growing up. Gene variants that have been so far dubbed as risk variants, i.e. enhancing risk behaviour, are shown in this study to increase early alcohol consumption in the group born at the end of the 80s but having a completely opposite impact in those born just six years earlier. Several similar findings have been revealed by the ongoing study.

„This will change how we understand and study the interaction between genes and environment for behaviour," professor Harro says.

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THE GREATEST SCALE

Zooming out from our planet, we first see the Solar System, then our galaxy, the Milky Way. This belongs to a galaxy cluster called Local Group, which in turn is part of the Virgo Supercluster of galaxies. And this is only one of millions of superclusters in the Universe.

These superclusters are not randomly distributed in space, scientists have found. Looking at the large-scale structure of the Universe they can see that clusters are connected with thinner filaments of galaxies, tens of millions of light years long. Jaan Einasto, the grand old man of Estonian astronomy, has proposed that on this level the Universe is structured like a honeycomb, a network of filaments with large voids between them.

"The study of the large-scale structure of the Universe also gives us information about the characteristics of dark matter," Einasto says.

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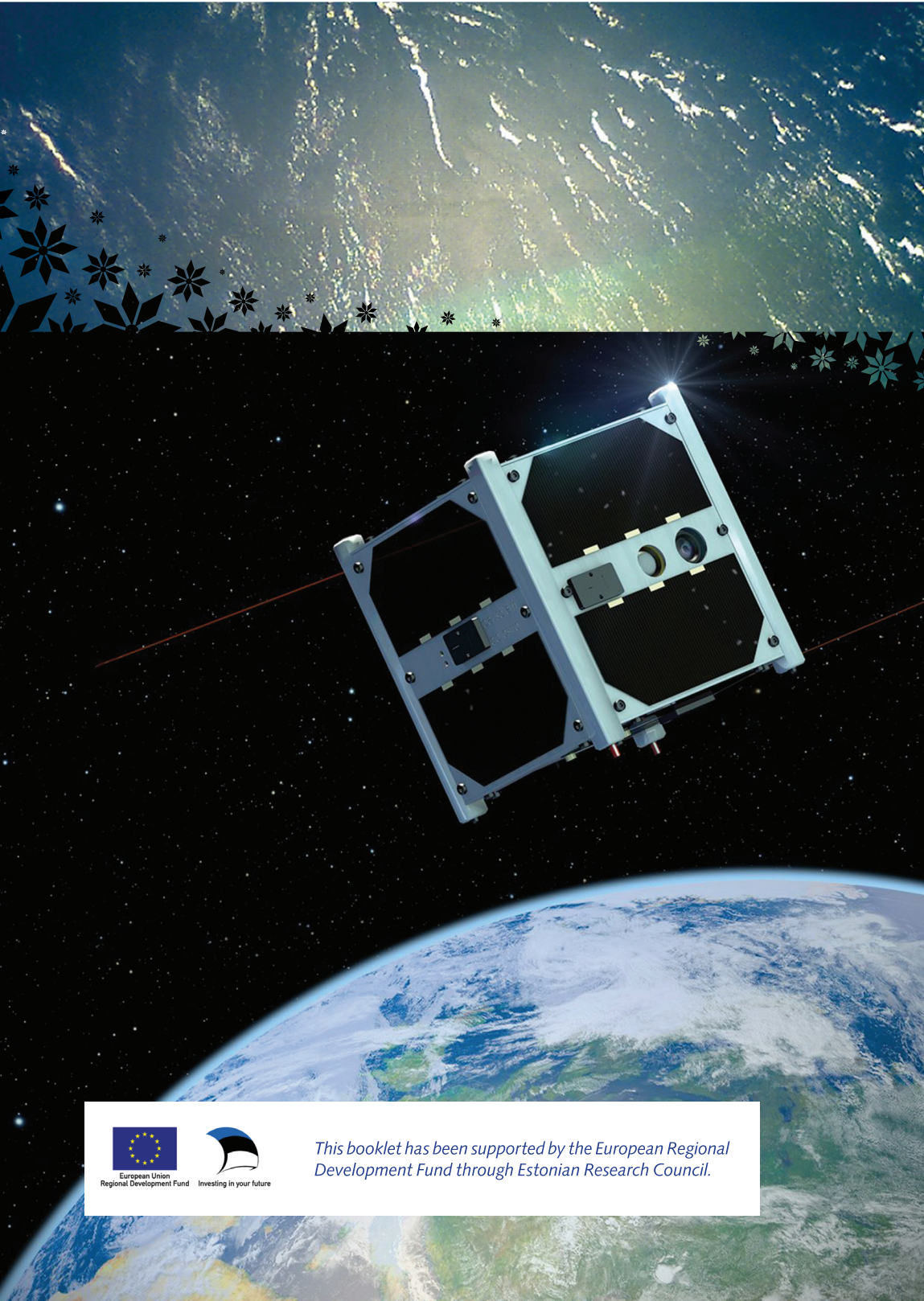

European Union
Regional Development Fund

Investing in your future

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