IGNITING THE DEEP TECH REVOLUTION!

On 22-23 September 2020, the EU's ATTRACT project brought its innovation eco-system together for an online conference. The goal: To help ideas in deep tech get out of the lab and into the marketplace.

ATTRACT

FROM OPEN SCIENCE TO OPEN INNOVATION

A Horizon 2020 project developing breakthrough technologies for science and society, ATTRACT is a pioneering initiative bringing together Europe's fundamental research and industrial communities to lead the next generation of detection and imaging technologies

PROJECT PARTNERS

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 777222.

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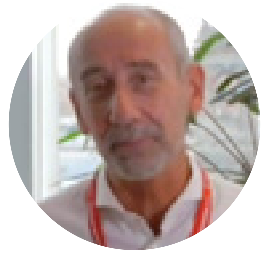
OF RESEARCH, INNOVATION AND ATTRACT



JEAN-ERIC PAQUET

Director-General for Research and Innovation, European Commission

Science and innovation are often seen as two different worlds, yet I believe the European Union is becoming increasingly successful in promoting the connection between them – for the benefit of all society.

In the ATTRACT project, funded by the EU's Horizon 2020 programme, we have seen a coming together of research and innovation: a bridge has been built from the laboratories of Europe's most spectacular research infrastructures and universities to the market, where businesses are developing innovative, high-tech products and services.

The ATTRACT project has been genuinely ground-breaking. It stimulated an ecosystem that has enabled researchers, industry, and young people to work together on developing 170 breakthrough 'deep tech' projects. ATTRACT is, I hope, a prelude to what we will see increasingly in the EU's next research programme, Horizon Europe, with dedicated support to enhance the European innovation ecosystem by drawing on our collective strengths and a renewed European Research Area, a borderless market for research, innovation and technology throughout the EU. ATTRACT supports the objective, defined by Commissioner Mariya Gabriel, of finding solutions to the challenges of COVID-19 and climate change by promoting research – ATTRACT puts science and knowledge on the path to becoming practical solutions to real problems.

This work is also of tremendous economic value, because deep tech — new commercial technologies emerging from fundamental science — is one of Europe's competitive edges, and one we must take full advantage of. Engineering and science are deeply European, and Europe has some of the world's finest research institutions. That is why it is vital that we turn this wealth of excellence into commercial success.

Now we have an opportunity to consider how we can build on what ATTRACT has achieved and bring its projects to the next level. The new European Innovation Council (EIC), for example, will invest in young deep tech firms to help them scale up. The overwhelming number of funding requests submitted to the EIC's pilot scheme has revealed just how much demand there is for deep tech investment.

In Horizon Europe, we can expect to once again be overwhelmed with great ideas and great innovations that just need the right kind of support to realise their potential. That's an asset to those of us looking for high-quality projects to support, and a challenge to applicants to be as competitive and innovative as their creativity and ingenuity allow.

But it also shows that the deep tech revolution is well underway — particularly in Europe. The 170 ATTRACT projects demonstrate that, too. I look forward to watching many of them scale up in the future, and to seeing them exhibit the true value of European research and innovation.

SERGIO BERTOLUCCI

Chair, ATTRACT R&D&I Committee
and professor, University of Bologna

As chair of the ATTRACT R&D&I Committee, it is my pleasure to provide a couple of introductory words to this special publication on ATTRACT.

The objective of ATTRACT's first phase, which now is ending, is the identification and initial development of breakthrough detection and imaging technology concepts, for expanding fundamental research frontiers and for upscaling future industrial applications and business. It promotes the involvement of national and pan-European research infrastructures and their associated research communities, industrial organisations (especially SMEs) and innovation and business specialists. Moreover, it proposes a co-innovation approach in which scientific and industrial communities jointly pursue and generate breakthrough concepts in close and equal partnership.

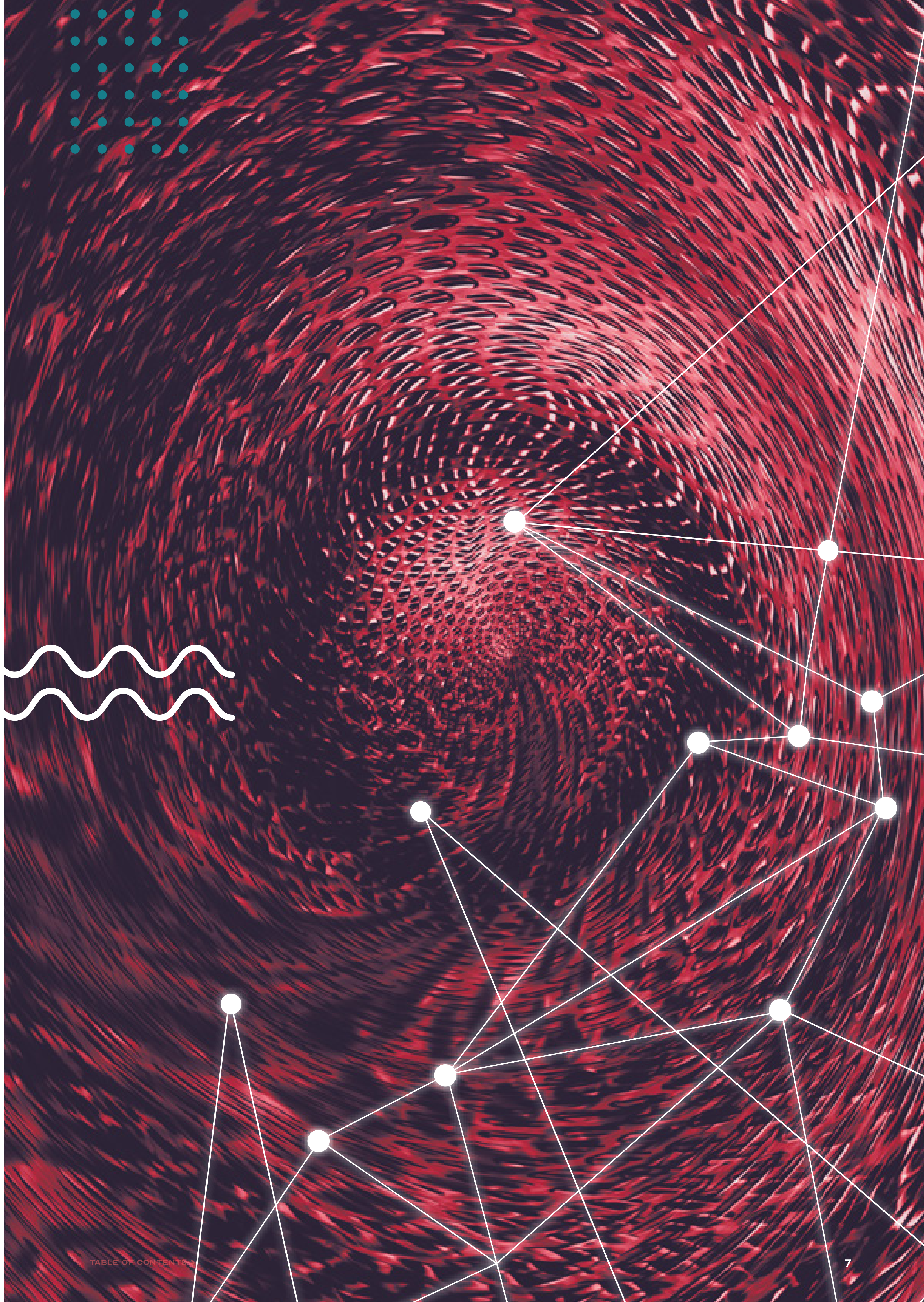
The ATTRACT project is operating under a new collaboration paradigm aligned with the 'Open Science, Open Innovation and Open to the World' philosophy.

So what have we achieved in Phase 1? Well, following the open call we launched in 2018, out of more than 1200 received applications for seed-funding for €100,000 each, our Committee selected 170 promising deep tech projects to develop their conceptual ideas further. To summarise what our current ecosystem looks like, 75% of the community is from research and 25% from industry, the latter comprising mostly SMEs and start-ups. Due to ATTRACT, over half of the projects have gained new industry contacts, permitting them to continue developing their early-stage technologies. About 60% of the projects have found the ATTRACT funding model unique and useful. Over a hundred, cross-disciplinary Master-level students have interacted with the selected projects to think of new areas of potential use. Some 50% of the funded projects are in sensor development; 30% in related electronics and computing, and 20% in software and integration. The main application clusters of projects are forming around sensor development (special hardware), instrumentation for new fields, and around health-biology-related challenges. Despite the dramatic effects of the COVID-19 pandemic, all projects have been able to make stunning progress, even if their originally planned access to labs got interrupted by COVID-19. In fact, six projects were even able to adjust their results to contribute to the efforts to fight the virus!

What's next? Well, we hope soon to be able to roll over to Phase 2, where we intend to select some 15 projects – or a cluster of them – from Phase 1, to further increase their Technology Readiness Level (TRL) and help them move closer to market and new areas of use. We are also working closely with the private investors, in particular with the small part of them that are genuinely interested in early-stage technologies and are not scared of the (in)famous "Valley of Death" – or should I rather say, "Valley of Debt".

And why do we want to do this? The ATTRACT Consortium feels strongly about the role of research infrastructures and fundamental research as the engine of innovation. We wish to help the community to make non-incremental advances in the use of advanced scientific instrumentation being developed for both scientific and wider use in society. We wish to engage the next generation of young scientists and innovators. The time has returned to take a leap into the future.

I hope you will find the attached report inspiring and illustrative in demonstrating what we have in mind.



SECTION II

ATTRACT AND THE DEEP TECH ECO-SYSTEM

ATTRACT systematises the process of pushing disruptive ideas towards market success

Some of the world's most exciting new technologies are being developed in European labs right now, but the researchers often lack the right connections, mechanisms and business savvy to develop them into viable products and services.

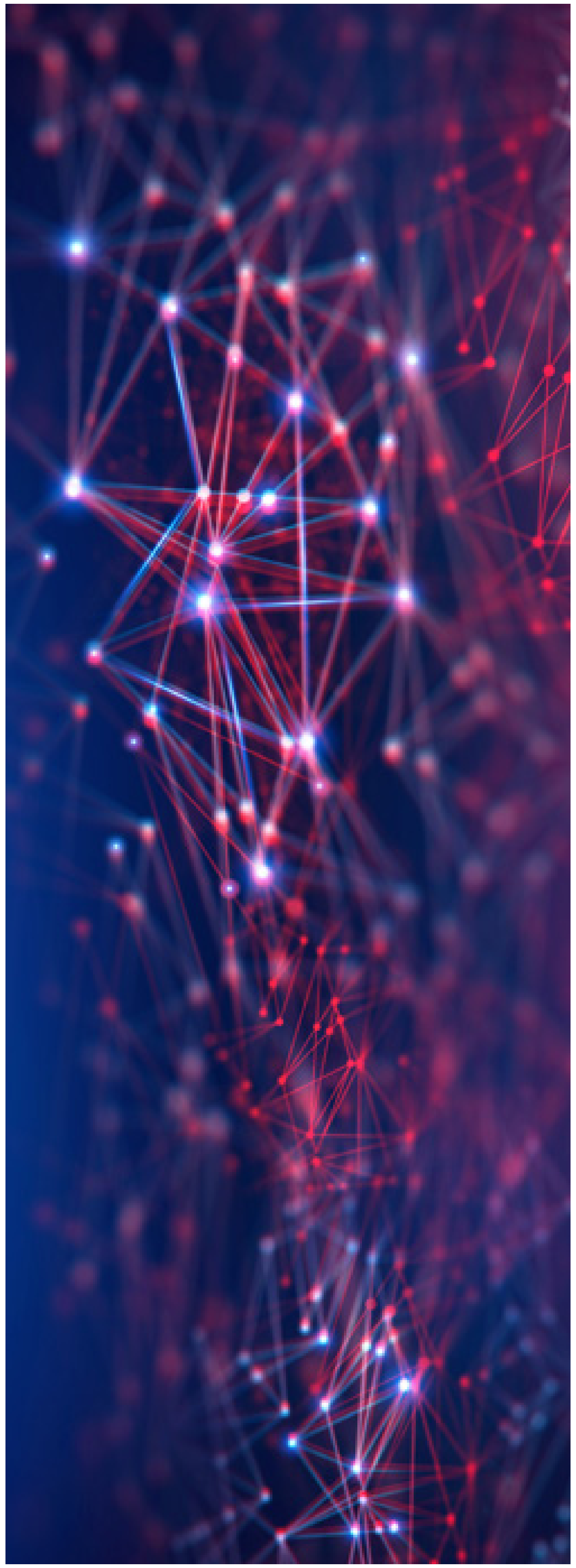
ATTRACT, a €20 million EU-funded project, seeks to address that by providing money, training, and access to industry. Since early 2019, it has been linking researchers, students, investors, business people and funders. The 170 projects it funds draw on emerging technologies in imaging, sensing, detection and artificial intelligence – "deep tech" – to create new cancer diagnostics, make chemical sensors out of bacteria printed 3D, or miniaturise space telescopes using graphene components. With its unique eco-system of research and industry, it aims to shake and stir all the right elements — from money to serendipity — to find successful applications and market niches for new technologies.

In an online conference September 22-23, the ATTRACT partners brought together several hundred participants to air preliminary results of the project's first phase – giving 170 grantees €100,000 each to start developing their scientific ideas into marketable products and services. From there the ATTRACT partners aim to select the best of the best among these ideas for further, sustained funding to reach their market targets.

It is, in essence, an experiment in new ways to organise government support for innovation, through creating a lively eco-system for public researchers and private partners to mix and work together in an open, sharing environment, observes Jonathan Wareham, a professor at Esade Business School in Barcelona, an ATTRACT partner.

At the conference, Wareham announced results of a study he led on the 170 ATTRACT project teams. The technologies involved are often "incredibly refined and sophisticated," he says. But the question ATTRACT asks is, "if these are developed for one scientific purpose, what mechanisms do we need to get them out of the [laboratory] infrastructure and into alternative applications where they can realise value for the European economy?"

Without deliberate intervention, it can take decades for those technologies to find their way to the market, if they ever make it at all. "ATTRACT is one of the ways which we have used to facilitate and to speed-up this process," says Sergio Bertolucci, chair of ATTRACT's independent research, development and innovation (R&D&I) committee, and former scientific director at CERN, the famed European high-energy physics lab that discovered the Higgs Boson in 2012 (but in the world of computing, is best-known as the birthplace of the World Wide Web in the 1990s.) In managing ATTRACT, CERN leads a group of nine research, university and business partners.



INGREDIENTS FOR SUCCESS

The WWW work – an off-shoot of the heavy computing expertise CERN had to develop for its primary scientific mission – shows how many complex factors have to come together for technology success; but while difficult, it isn't magic. "There's a tendency to romanticise the role of accidents or serendipity: scientists or engineers trying to solve one problem and some anomaly came out and they found another application," says Wareham, "we can't just go around talking about these little anecdotes. What we want to do with ATTRACT is put some purposeful governance on this serendipity process."

Michael Krisch, chair of the ATTRACT consortium board and a scientist at the European Synchrotron Radiation Facility in Grenoble, says European scientists are at the forefront of new technology ideas, but they often "do not make it into the market" and are "not exploited for the benefit of society." The idea of ATTRACT was to establish a framework for turning cutting-edge technologies into "breakthrough innovations with strong industrial applications," says Krisch.

170 PROJECTS SELECTED

ATTRACT is run by a consortium that includes six research infrastructure, the "big science" labs with even bigger computers that track atomic particles, and analyse the internal structure of essential materials and medicines. They have powerful skills at devising new ways to detect, study, image and understand tiny fluctuations in energy or matter – important for hospital medical scans, factory production lines, in-the-field crop monitoring and much more. Besides already-mentioned CERN and ESRF, the other consortium partners are the European Molecular Biology Laboratory, the European Southern Observatory, the European X-Ray Free Electron Laser Facility and the Institut Laue-Langevin. They are joined by two universities, Esade in Spain and Aalto University in Finland, and the European Industrial Research Management Association.

ATTRACT's 170 projects cover a diverse array of technologies that support advances imaging and detection, from fibre optic communications to 3D printing. Imaging and detection are "really part of a lot of fundamental research projects," and have uses in applied fields like medicine, says Cinzia Da Via, a member of ATTRACT's R&D&I committee. They form "the basis of the famous Internet of Things," which is "changing our life already in a very substantial way," says Bertolucci. About 35 per cent of ATTRACT projects have applications in the healthcare sector, and 70 per cent involve sensor technologies in various application sectors.

REAL-WORLD PROBLEMS

Besides money and access to industry, ATTRACT also provides "a lot of training in business planning, commercialisation, entrepreneurship — even things like legal matters, sales and marketing," says Wareham.

Most of the 170 participants came up with their ideas after being presented with a particular problem, but before working out fully how to develop their solutions into something ready for market, or considering how the results could be used in alternative fields they initially thought of. The Esade survey results show ATTRACT "gave them the opportunity to further work on those ideas," says Wareham, "not only because of the financial seed money, but also because of the eco-systems, the training, the network, etc." Participants found the connection to industry particularly useful, he says.

The largest number (41 per cent) of ATTRACT participants found new applications for technologies by combining them with other technologies. For example, the SCENT project, which is creating a new type of gas sensor, merges the very different fields of gas-sensing and high-pressure technology. More than a quarter of projects (27 per cent) found new uses by taking a technology from one field and applying it in another: the SIMS project, for instance, is developing a seismic monitoring system using sensors that were designed to look for gravitational waves.

ATTRACT also enables students from various disciplines to work with the projects, which "familiarises a large group of up and coming members of society with what these technologies are, what they're capable of, and what potential they have," Wareham says.

SECTION III

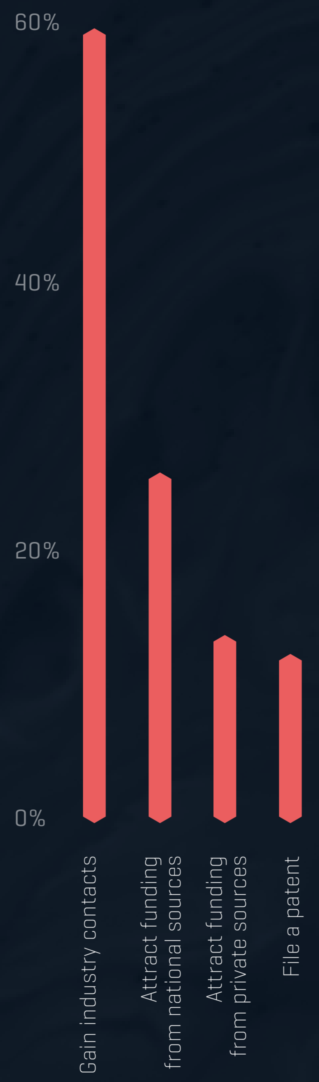
UNDER THE MICROSCOPE: A CLOSE LOOK AT ATTRACT

Prof. Jonathan Wareham of Esade Business School led a study of the 170 ATTRACT grantees, examining how this unusual innovation experiment is going in its first months.

THESE ARE THE RESULTS

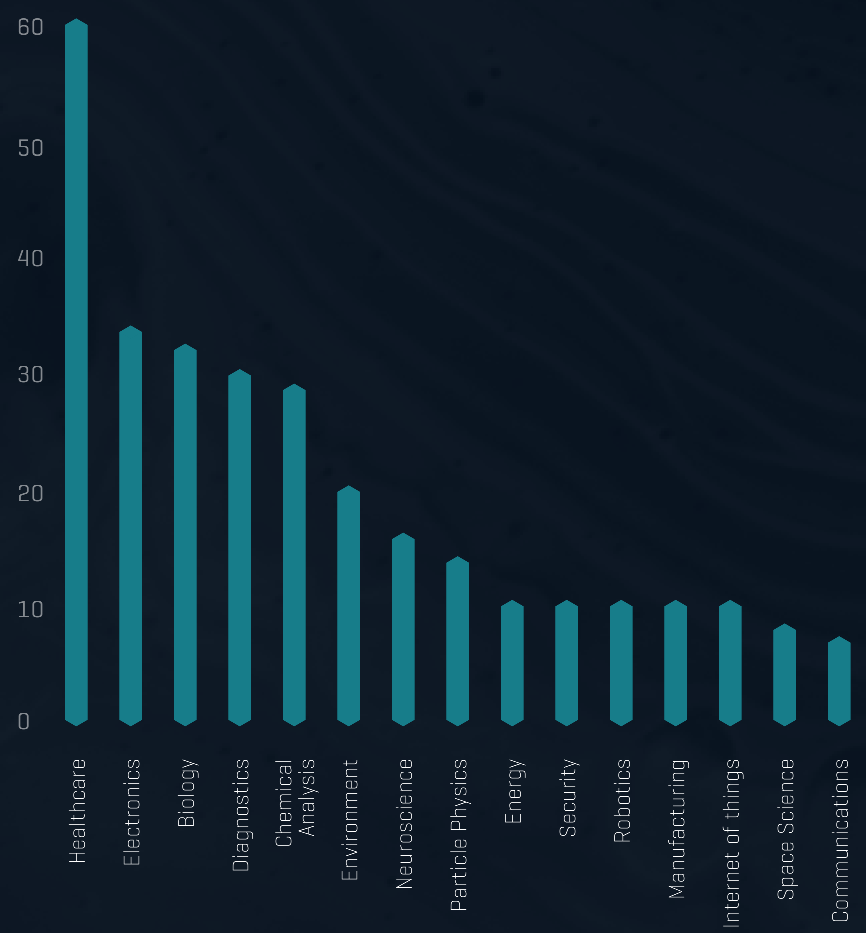
PROJECT OUTCOMES

Did ATTRACT enable you to gain any of the following?

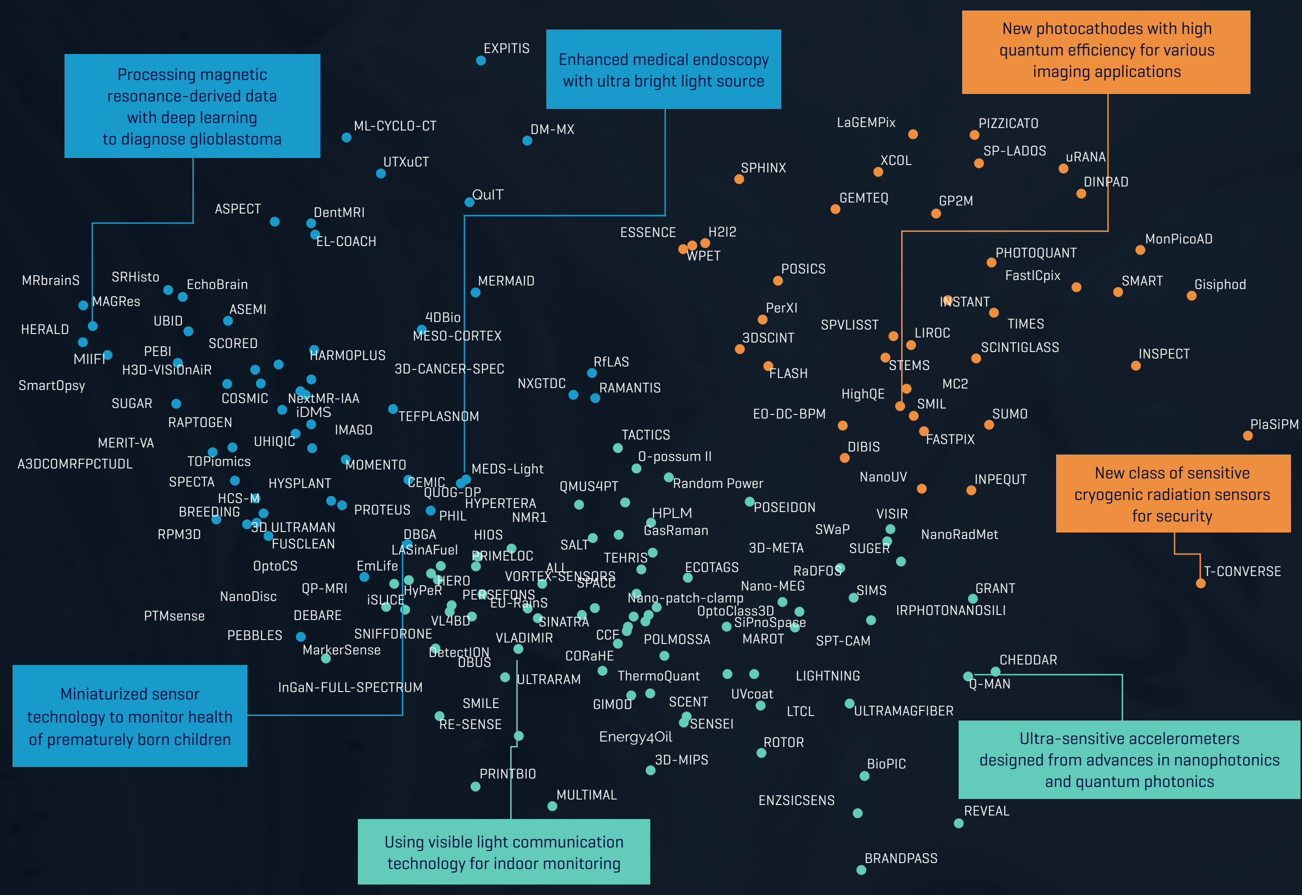


THE 170 ATTRACT PROJECTS BY SECTOR

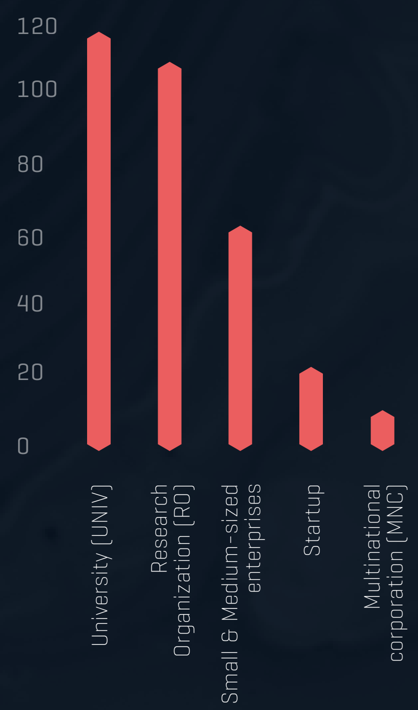
(some projects have multiple applications)



Visualisation of the 170 funded projects under ATTRACT, organised by keywords. The blue cluster refers to projects in healthcare, green to applications of detectors to various areas and orange to upstream advances in sensor technologies

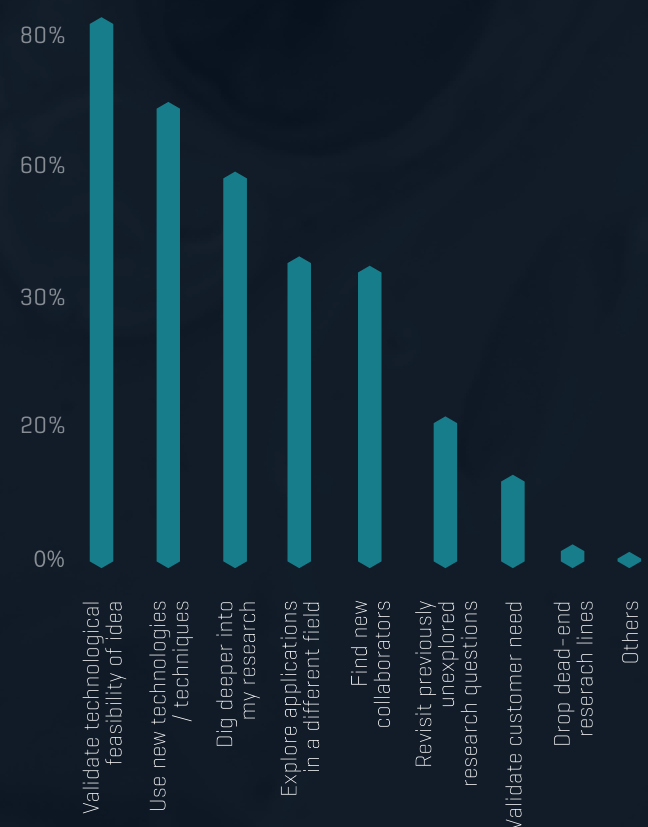


TYPES OF ORGANIZATIONS INVOLVED ACROSS ALL ATTRACT PROJECTS



ACTIVITIES PURSUED

With respect to your previous research, what new directions were you able to pursue due to ATTRACT?



SECTION IV

HOW DEEP TECH WILL SHAPE THE FUTURE

Advanced AI, the Internet of Things, gene editing, and synthetic biology will transform our lives in ways we struggle to imagine today – from talking toilets to home-made medicine

One of the characteristics of 'deep tech' - emerging, research-intensive technologies - is that we don't yet fully understand the market applications. It's hard to predict how individual technologies might be used in the future; and predicting how they might be used together is even more difficult.

Making sense of these technologies isn't about predictions, but "about being prepared," says Amy Webb, a well-known "futurist" who heads the Future Today Institute and is a professor of strategic foresight at New York University's Stern School of Business. Webb argues that a convergence of seemingly disparate deep technologies that's already occurring today give an indication of the impact they could have in the future.

"In 20 years we may not go to a clinic or a lab or a hospital to take a test; we might be printing our medication at home," says Webb.

TV dramas, meanwhile, could use "our own data from our own lives to tell us stories about ourselves," featuring synthesised characters built by algorithms, who look like they're played by real actors, but are in fact computer-generated.

These ideas sound futuristic, but what's less obvious is the connection between them. Webb says they're underpinned by the same deep technology trends: the exponential growth in the supply of data, and the increasing sophistication of the algorithms that can use that data and automate complex processes.

SYNTHETIC MEDIA AND SYNTHETIC BIOLOGY

AI-powered drama programmes would be an example of synthetic media, which already exists. Synthetic media consists of voices, images (including faces), narratives and characters that were generated by algorithms.

The data those algorithms draw on to create that media can be found everywhere. For example, Reuters trained an algorithm to create a sports presenter, with his own show. The algorithm — and not the humans who created it — used the footage from real sports broadcasts to generate the artificial newsreader (including his face, voice and clothing), to cut highlights from the football match he would report on, and to write his script.

At the same time, artificial intelligence algorithms are also driving advances in synthetic biology, creating the molecules and forms of life from scratch. Webb says synthetic biology is a step up from the CRISPR-CAS9 gene editing system, because it automates many of the laborious tasks that would otherwise be carried out by a human.

Synthetic biology can even create synthetic organisms: an AI system has already created a synthetic life form, called a Xenobot, made of skin and heart muscle grown from the stem cells of frog embryos. "It's a living machine and it's an entirely new kind of lifeform that never existed before," says Webb. Its creation required "a supercomputer, a virtual environment, and an evolutionary algorithm," not unlike Reuters' artificial sports presenter.

Microorganisms can even be printed: the ATTRACT project PRINTBIO uses 3D printers to structure hydrogel containing genetically-modified bacteria, which can detect certain chemicals by generating an electrical signal when exposed to them. The Emerging Life project, meanwhile, combines microfluidics and mass spectrometry technologies in order to study the emergence of autocatalytic networks: a central mystery of the origin of life, where molecules begin to catalyse one another's production so that collectively, they become self-replicating. Another project, 4DBio, aims to push the boundaries of fluorescent volumetric imaging, which would enable closer study of biological processes.

Another trend, alongside AI's encroachment into biology and the media, is the increasing number of products and services that collect and generate vast amounts of data about the people who use them, from their preferences to their mood and even their health.

Many consumers are already accustomed to data-driven health apps on their phone, and digital assistants that talk to them. But Amazon, which owns the Alexa digital assistant, recently released an Alexa-powered smart bracelet called Halo: it is foremost a fitness tracker, but it also "tracks your emotional state by listening to the tone of your voice all day long," says Webb.

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Another company, Kohler, has even created a toilet that connects to Alexa, "which means every time you go into the bathroom you can have a chitchat with your Alexa-powered toilet, if you want," says Webb. Why would you want to do that? Perhaps today you don't —but Webb argues that one day this technology could be used at home for routine urinalysis and tests for kidney inflammation, high blood sugar, or bacterial infection.

All of this data could be equally useful to provide us with services driven by synthetic media and synthetic biology. For example, an AI system could recommend medications based on personal health data drawn from myriad sources. The chemical (or even biological and genetic) composition of those medications could be digitally encoded and printed at home. Meanwhile, data about one's mood and preferences could help generate exactly the TV drama that would be most satisfying or cathartic at any moment.

This may sound far-fetched — especially to an investor being asked to put money into such technology. But if one had said in the pre-Internet age that, "someday we're all going to be connected wirelessly, we're going to be wearing smart glasses, we're going to go the bathroom on an Alexa-powered toilet, nobody would've believed you, and no investor would've given you money," says Webb.

Amy Webb

SECTION V

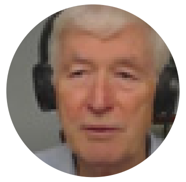
DEEP TECH WILL TRANSFORM SCIENCE

AI and Big Data are changing the way scientific experiments are designed and run, but access to data is a hurdle on the road to open science

One of the most obvious areas where deep tech is already having an impact on society and the economy is artificial intelligence and Big Data. Vast amounts of data are being generated by many different activities, from scientific experiments to social media. Those data both fuel and raise demand for the algorithmic tools that can draw insights from it, and which underpin digital services that in turn generate even more data. That's an opportunity for data-intensive science; but scientists often face obstacles when trying to access data.

"A lot of experimental science now has huge datasets," says Tony Hey, chief data scientist at the Science and Technology Facilities Council, a research agency of the British government. For example, some experimental lasers produce so much data that they can't even be stored on a pen drive, let alone analysed with conventional methods. But "you can use AI tools to find things in the data and put them all together," says Hey.

Besides simply analysing existing data, AI can automate the processes that generate that data in the first place. For example, in automated laboratories, AI is used to carry out scientific experiments. "In the next ten years I think you will see a transformation in science," says Hey, who believes advances in AI will mean "we can do science in a much more efficient and better way."



Tony Hey

GOOD FOR THE PLANET, GOOD FOR MAKING MONEY

Some of Europe's best deep tech opportunities are in green applications, says Mark Ferguson, chair of the European Innovation Council's advisory board.

Controlling climate change is a top EU priority, and technology can help, says Ferguson. There can be tools for carbon capture and re-use, for sustainable food production, for reducing agricultural emissions or even artificial meat.

Food tech has "just undergone a revolution," he says, "Imagine that you could actually dial up the composition of a piece of meat: you could 3D print it, you don't have any supply chain issues."

Such technologies present "a tremendous business opportunity: it's an opportunity to do good for the planet and make money at the same time, " says Ferguson.

The opportunity lies in "stuff where Europe has historically a good track record in what you might call traditional technology or engineering," he says. "We probably are not going to be starting a mega digital advertising company," but building dominant European firms out of the digitalisation of agriculture or energy is "absolutely on the cards."

Mark Ferguson

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THE UNTAPPED VALUE OF SOCIAL MEDIA DATA

Barbara Pernici, professor of computer engineering at the Polytechnic University of Milan, says the way people are using computers now is as significant to data-driven science as is the computational power on which it relies. For example, the vast amounts of data being generated every minute by use of social media could improve the way the authorities respond to disasters, if scientists find a way to analyse it all effectively.

After an earthquake or a flood, "you don't really know what has occurred," says Pernici; "you need evidence from the ground to know what to do and to provide information, to be able to reach the place and provide the needed assistance." She says social media is one way to get this information, because people post what they see and experience; Twitter is especially valuable because it is publicly available. However, simply sifting through tweets for useful information, particularly useful images, is "a bit like looking for a needle in a haystack," Pernici says. Instead, "you can get help from the crowd" by using AI to select images automatically and then asking Twitter users in the area whether they're relevant.

However, a lot of potentially useful data is held by private companies and can be difficult to access, says Tuuli Toivonen, professor of geoinformatics at the University of Helsinki. Europe has good data on the environments in which people live and move, but when it comes to what people are doing in those environments "we actually don't have very good access to most of the individual level data that we as citizens produce," says Toivonen. "It's user-generated data," but "almost all of that is owned by private companies." Researchers can negotiate individual agreements with companies to access particular data, but open science requires broader access.

The data that companies like Twitter do make available are just the "tip of the iceberg," says Hey; but it's hard to expect open access when the data fund services provided free of charge. "Openness doesn't always mean that it has to be cost-free, but it has to be somehow transparent," argues Toivonen. "We do need to have mechanisms for funding the data that we want," she says.

But for science to benefit, "just getting the data is not sufficient," says Pernici. What's also needed are communities that can curate the data and assess its quality. "Quality control in this process is very important," she says.

Barbara Pernici

Tuuli Toivonen

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SECTION VI

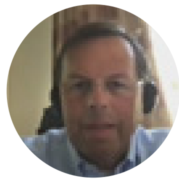
PREPARING THE NEXT GENERATION OF DEEP TECH BUSINESS LEADERS

Teams of university students helped ATTRACT technologies develop new applications, learning valuable lessons about the business of technology

One of the deep tech challenges that ATTRACT attempts to solve is finding uses for new technologies. Some revolutionary technologies, such as the Internet, were developed without a clear idea of how they might be used in the future or what types of businesses they might support. But new technologies could find markets faster if those developing them knew a little more about business, and if business people better understood the potential of early-stage technologies.

One way to achieve that is through education. "Making entrepreneurship and innovation training a part of regular masters and PhD programmes" is key, says Frank Gielen, education director at EIT InnoEnergy, an energy partnership set up by the European Institute of Innovation and Technology (EIT). It's "super important that generalists and experts, or future generalists and experts, learn how to work together," remarks Lisa Gerkens, head of product strategy at Forward31, a team at Porsche Digital focused on creating new business models.

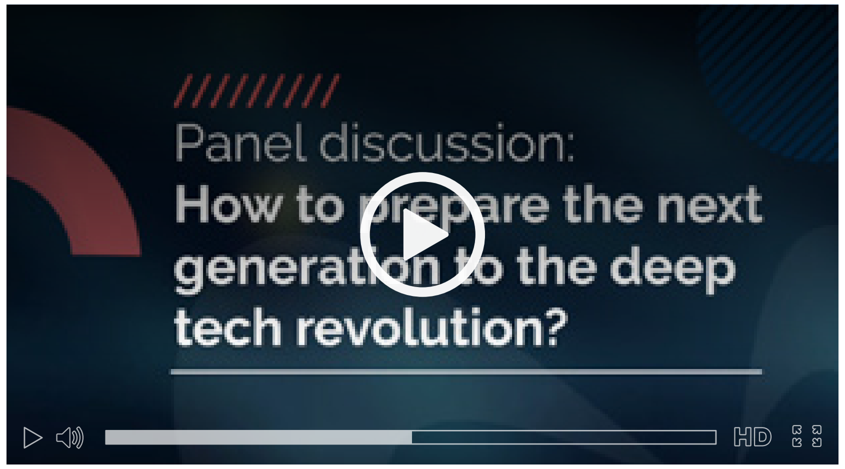
Putting that thinking into practice, two members of the ATTRACT consortium — Aalto University in Finland and the Esade Business School in Barcelona — connected students in 2019 and 2020 with tech startups to find commercial uses for new technologies, and to develop those technologies into new products. "The role of the teacher is changing. They need to be able to bridge companies with universities and with students," says Sumathi Subramaniam, a higher education policy officer in the European Commission.



Frank Gielen

Lisa Gerkens

Sumathi Subramaniam



DETECTING STROKES AND MEASURING RAINFALL

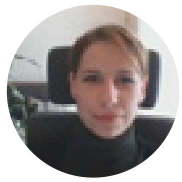
PhD students researching virtual reality (VR) at the Aalto Design Factory partnered with Finnish startup Hitseed, which had created a sensor chip capable of processing data independently, without the need to transfer it to a larger computer. Together they developed a virtual reality exercise system for use in the rehabilitation of stroke patients, called Stèlo. The Stèlo module, which contains the Hitseed chip, tracks and analyses movement data from various parts of the body. The processed data then supports a series of VR exercise games designed to help patients recover their mobility.

"At the very beginning our team explored multiple ideas in how the Hitseed technology could be used," says Sofija Jākobsone, a product design student at Riga Technical University in Latvia who worked on Stèlo while taking part in the course at the Aalto Design Factory. "We wanted to explore potentially using technology for medical purposes," says Jākobsone. To work out what was needed and to make initially vague ideas concrete, "we needed to come out of our shells and actually talk to people," she says.

Apurva Ganoo, a master's student in international design business management at Aalto, worked with SkyEcho, a Rotterdam startup developing software to monitor rainfall. He and five other students helped the firm develop various prototypes, including a mobile video game that analyses how players react to weather information, by having them care for virtual crops. "When you're working with technology, you need to understand how people are interacting with it" says Ganoo. To that end, "we tried, tested, failed, and developed multiple prototypes," he says.

Cecilia Bautista Rosell, who is studying business analytics at Esade, had the opportunity to participate in an ATTRACT-funded project called HYSPLANT, which aims to improve the survival rates of embryos conceived through in-vitro fertilisation.

HYSPLANT researchers at the Institute for Bioengineering of Catalonia had developed technology for monitoring metabolic changes in embryos, and were looking for the best way to deploy it clinically. Bautista and other students from Esade and the Polytechnic University of Catalonia conducted hundreds of interviews and surveys, before deciding to integrate the technology into a stackable incubator. "It really opened my mind to working in areas that are different to those typically chosen by business students," she says.



Sofija Jākobsone

Apurva Ganoo

Cecilia Bautista Rosell

NAVIGATING THE 'JUNGLE' OF DEEP TECH INNOVATION

Some European researchers and entrepreneurs are already turning deep technologies into products, but they need help navigating the "jungle" of funders, investors and commercial partners they will rely on to succeed.

"There is a lot of funding out there, but it's truly a jungle if you're a young startup," says Kathrin Brenker, CEO of Optobiolab, a German biotech start-up supported by ATTRACT. Navigating the range of funding options – not all of them appropriate – "is really a struggle," she says, "it would be nice if we had a higher organisational structure to tell startups where to go."

One way to achieve that is to create more and bigger platforms where investors and entrepreneurs can securely share information — enough to build trust without exposing young firms to unnecessary commercial risks, says Martijn de Wever, CEO of Floww, a fintech company in London.

Linking small and large firms is also important because they can play different roles, says Matthias Kaiserswerth, managing director of Hasler Stiftung, a Swiss foundation for ICT and education. He says start-ups innovate while large firms optimise. "Large enterprises typically are good at running their established business: they optimise things for efficiency;" but it's harder for them to take risks with new ideas, because "whether something is disruptive or not, you only know after the fact." By contrast, the start-up ecosystem is good at "doing experiments in the market; start-ups can go belly-up when things don't work. Maybe the technology survives and another start-up picks it up," says Kaiserswerth.

But alongside this networking, start-ups also need to be made aware of the importance of protecting their intellectual property from those who might steal their ideas, says de Wever. "In the U.S. building up your IP portfolio is a natural thing to do as part of your company. But over here it's not something that's part of the culture," he says. "People are quite open about it and sharing ideas, and don't actually get to the state of protecting their technology.

SECTION VII

OVERCOMING OBSTACLES TO DEEP TECH FINANCE

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Effective cooperation between the public and private sectors and early support for startups are key to overcoming Europe's investment gap.

Deep tech investment is a game of high stakes and high risk. Once developers of new technologies have reached the prototype stage — which ATTRACT helps them to achieve — they need a substantial amount of investment to reach the commercial scale necessary to compete on the open market. Even with sufficient investment, success isn't guaranteed, but rewards can be great for investors willing to accept the risk. The question is how to connect deep tech developers with such investors, as well as what can be done to reduce the risk and encourage investors to support deep tech.

"Deep tech projects are highly risky, and very often the investors are reluctant to support young companies, to support a risky project," says Fabienne Gautier, head of the innovation ecosystems unit at the European Commission's Directorate-General for Research and Innovation.

"Public funding is key, I believe, in supporting innovation," but there is "a gap in bridging public funding and private investment," says Gautier. The new European Innovation Council, which us run by the Commission, aims to bridge that gap by buying equity in firms and encouraging private investors to follow. "This will attract other investors, because we will be those which will step in first in those promising companies," she says.

EIC MAY BLOCK FOREIGN TAKEOVERS OF EUROPEAN TECH

In its mission to support innovative companies, the European Innovation Council (EIC) could buy "golden shares" to stop foreign investors from taking over strategically important European tech firms, says Jean-David Malo, the agency's director at the European Commission.

Golden shares give the holder veto power over certain transactions, such as mergers. Malo says the EIC may use them if a firm's work is of strategic importance to Europe in, for instance, vaccines or artificial intelligence. He points to the growing importance of AI: "if you can't grab this, if you cannot have 'hands-on' on this, it is our own vision of what it means to live in society which is at stake."

Malo says the EIC has an "absolutely obvious role" to play in establishing "tech sovereignty," developing key technologies domestically and relying less on suppliers outside Europe. "It is absolutely vital that we keep in Europe a number of technologies on our own, because otherwise we will be in the hands of other countries," such as the U.S. and China.

The EIC began in 2018 as a Brussels experiment in updating its tech-company support schemes, and is about to get a big budget boost from 2021 onward – including enough cash to make it one of Europe's biggest venture capitalists. The idea: to encourage private VCs to invest more money in European tech start-ups, by contributing to equity fund-raising rounds in a way that would make those investments a little less risky for the private partners. "The idea is that, gradually, we will leave the capital of the companies and the private sector will jump in, because our objective is not to crowd out the private investment," says Malo.

Money is important, "but what is absolutely even more important, in reality, is to provide a friendly eco-system for a company to flourish," says Malo.

Fabienne Gautier

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FINDING MARKET RELEVANCE FOR NEW TECHNOLOGIES

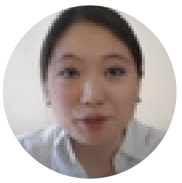
The German government has already implemented something similar on a national level with High-Tech Gründerfonds, set up 15 years ago. It now manages a total of €900 million across three funds, the most recent of which consists of 60 per cent public and 40 per cent private funding, says Marie Asano, investment manager at HTGF. Asano says working with industry is key to understand the commercial viability of new technologies and to make good investment decisions, "no matter how good a scientific innovation is, if there's no market relevance, it's not going to happen."

Finding that market relevance can take a long time, however. Georgio Rossi, professor of physics at the University of Milan, says that while he was working at a linear accelerator in France in the early 1980s, "there were touch screens in the control room," but "it took over 30 years before the touch screen became a daily tool" in consumer products. Maybe that could've happened sooner if there'd been an effort to find market applications for these new technologies, he says.

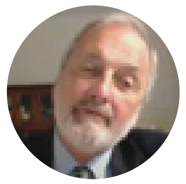
Public sector involvement, meanwhile, brings more than money, says Léopold Demiddeleer, honorary chairman of the European Industrial Research Management Association (EIRMA) and formerly chief technology officer at Belgian chemical company Solvay. "It brings social relevance, because by definition in industry, we sometimes are — we have to confess it — blinded by money," says Demiddeleer. Start-ups often target big societal challenges in ways industry does not, so public funding helps those ideas evolve.

Public investment in fundamental research infrastructure is also important for the long-term development of deep tech, says Rossi. He points to the construction of Brazil's national synchrotron light laboratory in Sao Paolo state, which boosted high-tech skills in local industry because scientists had to train suppliers to build what they needed.

What Europe really needs is a single place where public funders, private investors, start-ups and industrialists can find one another, as well as a single point of information for matters such as grants and business plan modelling, says Asano. She says early advice on intellectual property protection is also crucial, as start-up firms often end up signing bad IP transfer agreements with the universities from which they spin out.



Marie Asano



Georgio Rossi

Léopold Demiddeleer

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5 RECOMMENDATIONS FOR A EUROPEAN DEEP TECH ECO-SYSTEM

Getting disruptive ideas out of the lab and into the market is no easy task. At an online workshop organised 8 September by media company Science|Business, ATTRACT participants discussed what European government could do to simplify that work.

This is what they recommend.

01 PAY MORE ATTENTION TO DEEP TECH

Early-stage technologies being developed by scientists may not have well-defined commercial applications yet, but many will need early funding before they can reach that stage.

02 CREATE NETWORKS OF INNOVATORS, FUNDERS AND INVESTORS

Start-up founders take risks on new ideas and find new markets, but they often don't know what grants to apply for or how to find private investors and commercial partners. Start-ups are often drawn to the US and to Silicon Valley, with which the EU struggles to compete in technology. New platforms to create networks across European nations could help address that problem.

03 ORGANISE MULTI-STAGE FUNDING FOR TECHNOLOGIES AT DIFFERENT LEVELS OF DEVELOPMENT

Developers of new technologies need different kinds of support depending on where the technology and the business model is up to. Technology Readiness Levels (TRLs) provide a useful scale for defining what public grants should target, but beneficiaries need opportunities to move onto new kinds of support once they've completed earlier grant agreements. Multi-stage support would help move technologies up the TRL scale quickly and prevent them from running out of money after succeeding at earlier stages.

04 HELP START-UPS AND SPIN-OUTS UNDERSTAND THREATS TO THEIR INTELLECTUAL PROPERTY AND HOW TO PROTECT IT

Academia and business are different worlds where different rules apply. Scientists have to cross from one world to the other when they turn their work into commercial products, and they need to understand the risks they will encounter when they step into the business world for the first time. Universities can prepare them by providing well-organised, well-publicised and accessible technology transfer offices that can make sure they have access to legal protection from the very beginning.

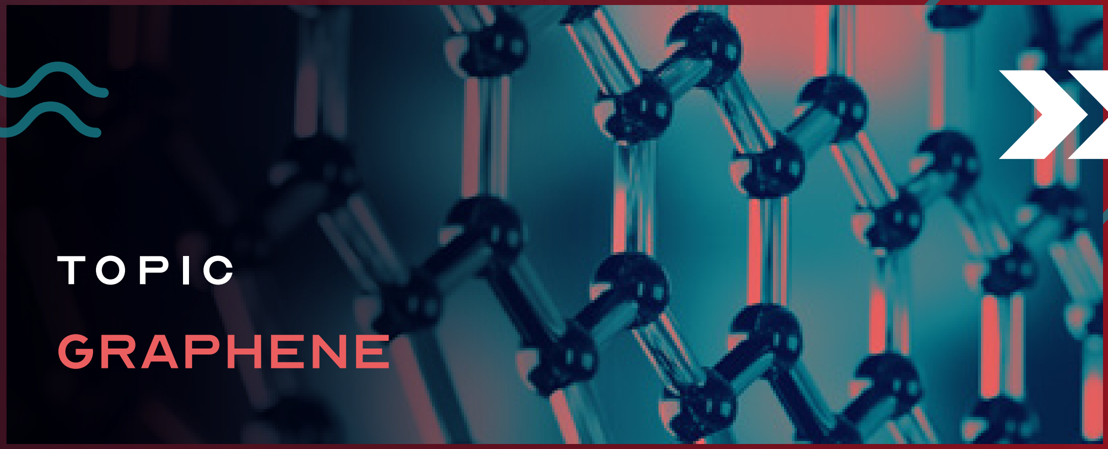
05 KEEP POLITICS OUT OF SCIENCE AND TECHNOLOGY FUNDING

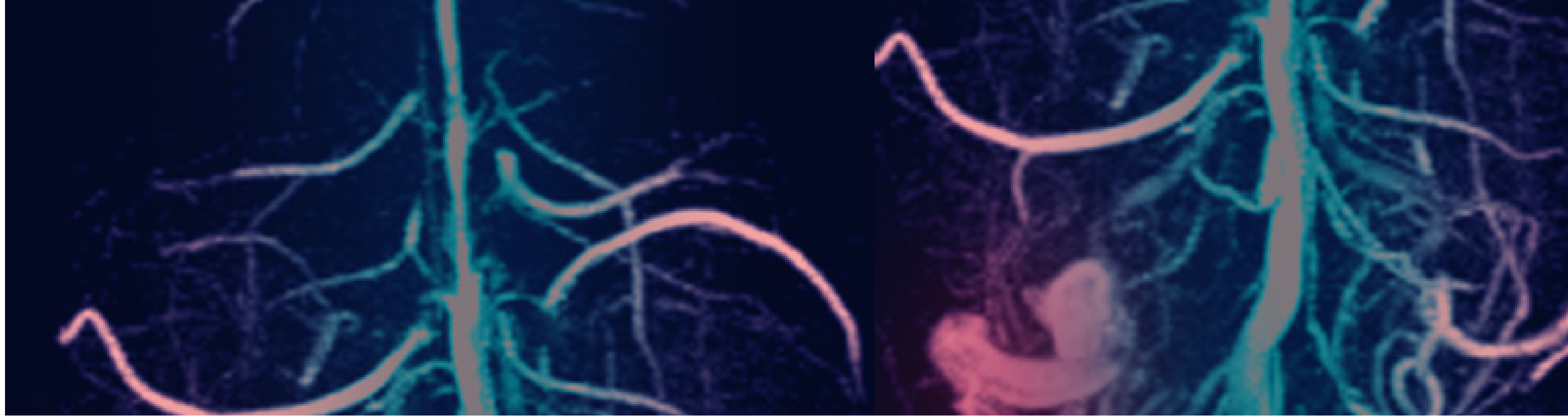
Politics shapes EU research programmes, but it can also undermine them. In the US, a lot of public research funding comes from defence budget, much of which is kept secret. That provides a degree of insulation from political trends. Military spending in Europe is mostly a national matter, but EU bodies like the European Research Council (ERC) show that it is possible to protect funding decisions from political priorities.

SECTION VIII

WHAT'S IN ATTRACT? A LOOK AT SOME OF THE PROJECTS

In all, 170 different projects make up what is today ATTRACT. They are in many fields of application, including healthcare, materials, earth observation and more. What they have in common is the underlying 'deep tech' they draw upon, in imaging and detection. Here, a random sample of a few of the application areas represented.





TOPIC
MAGNETIC RESONANCE IMAGING (MRI)

EXPLORING THE BRAIN IN AUGMENTED REALITY

The MRbrainS project is trying to make intricate neurosurgery easier with holographic brain-mapping software, which highlights and labels crucial areas and blood vessels right before the surgeon's eyes.

MRbrainS feeds brain activity data from functional magnetic resonance imaging (fMRI) into dedicated software for brain-mapping (called a neuronavigator), then integrates that into a mixed reality headset, which overlays 3D digital images on to the wearer's view of the real world. These images can be linked to objects in the real world and remain anchored to them as the wearer looks around.

Today's neuronavigators display 2D images on screens, forcing the surgeon to mentally link what's on the display with the patient lying on the operating table. That's difficult and "slows down the whole procedure," says principal investigator Antonio Ferretti. But using a mixed reality headset to tie 3D information directly to what surgeons see in front of them means they can rely on hand-eye coordination, "which is easier if your hands are in front of you, in the same direction you are looking," explains Ferretti.

OPERATING INSIDE THE WOMB WITH MIXED REALITY

The MIFI project is developing a mixed reality system that integrates MRI, ultrasound, and endoscopic video for surgery on unborn children. In-utero surgery is especially difficult, because doctors "need to operate on a patient inside another patient," notes Mario Ceresa, MIFI's principal investigator. That patient is very small and delicate, and depends on an amniotic sac that can quickly collapse, so "the interventions are very difficult, because there is a lot of time pressure," adds Ceresa, a postdoctoral researcher at Pompeu Fabra University (UPF) in Barcelona. Another challenge is that since the operation is keyhole surgery, the surgeon has only a very narrow field of view inside the womb through an endoscope, a tiny camera on the end of a long, thin fibre optic cable.

MIFI aims to improve the surgeon's field of view by displaying a virtual 3D image of the mother's womb in mixed reality, on top of what the doctor sees in front of them. The project applies machine learning to pre-operative ultrasound and MRI scans to identify relevant blood vessels—some of which are extremely small—and to help the surgeon find them in the womb, even if the baby has moved in the meantime.

FIGHTING BRAIN CANCER WITH MACHINE LEARNING

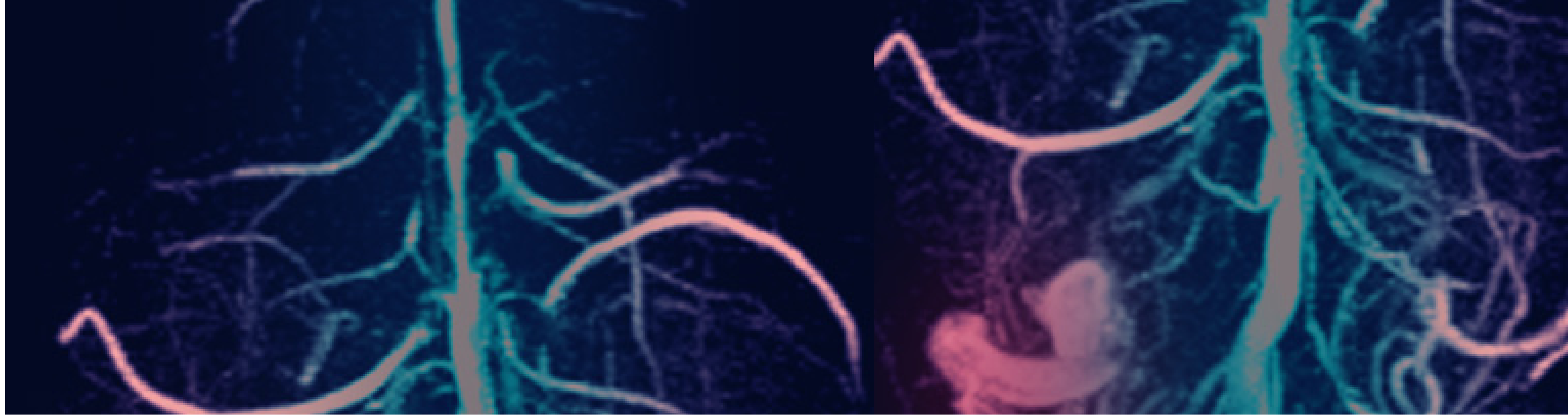
The MAGRes project aims to make MRI more effective at monitoring glioblastoma—an extremely aggressive form of brain cancer—by identifying subtle variations in MRI scans. The MAGRes researchers use magnetic resonance spectroscopy imaging (MRSI) to identify metabolic changes in the tumour. They then link these results to barely-perceptible changes in ordinary MRI scans, in order to develop new machine learning models for analysing MRI. The idea is not for glioblastoma patients to undergo MRSI—which takes much longer than MRI—but for MRSI research to make MRI analysis more effective.

"This metabolic information can appear before anatomical information seen by MRI," explains Ana Paula Candiota, MAGRes principal investigator and postdoctoral researcher at the Network Centre for Biomedical Research and the Autonomous University of Catalonia. The hypothesis is that "we can use the metabolic information to try to guide ourselves to find things on the [MRI] image that maybe we did not know," she adds.

BIODEGRADABLE IMPLANTS TO REPAIR BODILY TISSUES

In the QP-MRI project, researchers at the University of Turin and the University of Aberdeen are using a variable-field strength MRI scanner to monitor the structural integrity of a new type of medical implant. The implants, used to repair bodily tissues, such as bone, cartilage or corneas, are made from a biodegradable polymer lattice, bonded to an amino acid called polyhistidine, which shows up brightly in MRI scans. When the lattice begins to break down, the MRI signature of the polyhistidine fades.

The lattices are supposed to break down once their job is done, but the point is to ensure they don't deteriorate too early. Such polymer lattices are already in medical use; QP-MRI's novelty is the use of polyhistidine as a contrast agent, along with an MRI scanner capable of operating at variable magnetic field strengths, designed by the team at Aberdeen. "Our system uses a completely new mechanism in order to produce contrast in an MRI machine," says principal investigator Simonetta Geninatti Crich, a professor of molecular biology at Turin.



ANALYSING TEETH AND GUMS WITH MRI

The DentMRI project is using low-strength MRI scanning to improve dental care, by providing the first ever images of teeth and gums together that are good enough for medical diagnosis. The researchers, based at the Polytechnic University of Valencia and MRI equipment manufacturer Tesoro Imaging, have developed a prototype scanner that can accommodate objects of up to a cubic centimetre, and the goal is to build one large enough for a person to put their head inside for a dental scan.

ENABLING ELECTRONICS AT EXTREME TEMPERATURES

The Low Temperature Communication Link (LTCL) project could help to make MRI equipment more efficient by redesigning the way the powerful magnets inside an MRI scanner are connected to the rest of the system.

MRI magnets are kept cool with liquid helium, which has a boiling point of -269° Celsius, or about four Kelvins. Normal electronics can't function at such low temperatures, so they are built outside the cryogenic vessel that contains the magnets and connected with wires. But LTCL aims to develop electronics that could work inside the cryogenic container, with a wireless communications link and wireless power supply to the normal temperature environment outside.

FINDING SCARS IN HEART TISSUE FAST

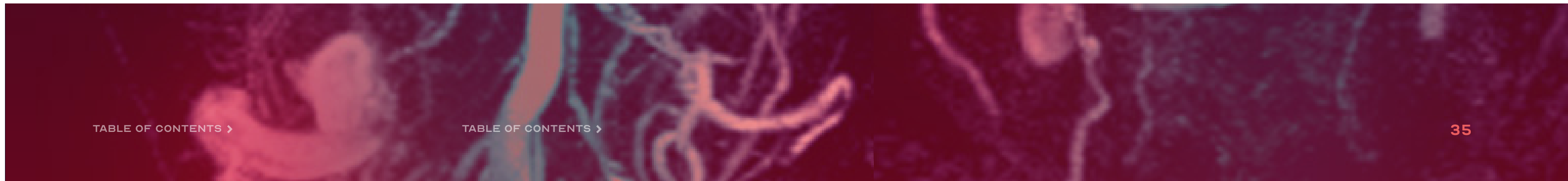
MERIT-VA is trying to improve the way major surgery is carried out. The researchers, based at the Teknon Medical Centre in Barcelona, UPF, and software firm Galgo Medical, are using machine learning to analyse data from MRI scans and electrocardiograms (ECGs) to improve planning of a particular type heart surgery.

Scar tissue formed after a heart attack can disrupt the heart's natural electrical pulses by directing the current where it shouldn't go, causing an irregular heartbeat (arrythmia). The condition is treated by inserting tiny catheters into the heart that destroy the problem tissues with radio waves. These catheters contain sensors that provide their position in 3D and detect electrical signals to identify the tissues that need removing. This information can then be displayed on an electro-anatomical map (EAM) to guide the surgeon.

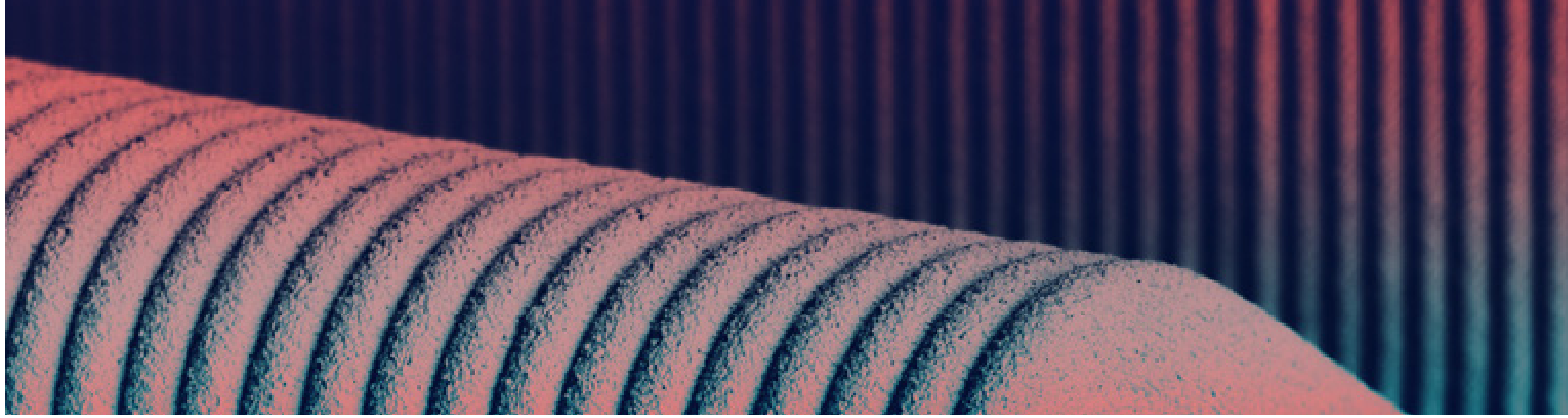
But building this map using the catheters can take hours, increasing the risk that something will go wrong during surgery. The condition also frequently recurs after treatment. The more the surgeon knows about which scars to target and where to find them, the quicker the procedure and the greater the chance of curing the condition without destroying excess tissue unnecessarily.

GETTING MORE FROM MRI DATA

The IMAGO project aims to develop new models of MRI analysis using a technique called single particle tracking (SPT) to monitor the behaviour of light in sample tissues. Unlike MRI, SPT can identify tiny, sub-microscopic features, but MRI can "see" inside the body whereas SPT can't. The IMAGO experiments aim to link the characteristics of different samples to subtle variations in MRI data, so that more information can be gleaned from MRI scans. The project is a partnership between Italy's National Research Council and the Sapienza University of Rome.



TOPIC
3D PRINTING



PRINTING INTRICATE GLASS STRUCTURES

The OptoGlass3D project brings together two cutting-edge technologies: an ultra-high-resolution 3D printer and a new substance called Glassomer, which combines particles of glass with a light-sensitive polymer that's liquid at room temperature, but can be solidified by the printer's laser. The printed Glassomer is then baked in an oven where the polymer burns off and the glass particles fuse together, leaving high-purity silica glass. Glassomer is the eponymous invention of a start-up based at the University of Freiburg, while the 3D printer is produced by Nanoscribe, a small business in Karlsruhe.

Uses for these glass structures could include optical communications, high-powered lasers, filtration and cell culturing, says Feredrick Kotz, chief science officer at Glassomer. "Normally these things are done with polymers," but polymers lack the opacity and resistance to extreme temperatures and chemicals offered by high-purity glass, he adds. High opacity is important for optical data processing, as well as for high-powered lasers, which also require heat-resistant materials; while various industrial and scientific applications need materials that can cope with hazardous chemicals.

"People always wanted to use glass in these applications, but it was not always possible, because shaping with these high resolutions was not possible," notes Kotz. Pure glass—silicon dioxide—melts at such high temperatures that it's hard to create solid moulds for it, and lower-purity glass lacks the desired properties. These industrial uses also require much smaller and more intricate structures than other glass-shaping methods can achieve.

3D-PRINTED LIFE

Even living organisms can now be 3D printed. In the PRINTBIO project, a team at Spanish firm Nanoelectra and the Madrid Institute for Advanced Studies (IMEDIA) use 3D printers to structure layers of hydrogel, which contains genetically modified bacteria that produce a bioelectric pulse when they come into contact with certain chemicals.

By using graphene electrodes to pick up these pulses, the printed bacteria serve as chemical detectors that can be used to observe water pollution or to monitor food quality.

"It's not just that the bacteria are recognising the compounds," explains Abraham Esteve Núñez, chief science officer at Nanoelectra, "we are also domesticating the bacteria to report to us what is around."

3D PRINTED PIPING

Smart Wall Pipes and Ducts (SWaP) is using 3D printing technology to create hydraulic pipes with temperature and pressure sensors embedded within them. These pipes could be used to cool advanced scientific instruments, such as CERN's gigantic atom smasher.

The pipes, wires and connectors are all created together from the same metal in the same print job, "then we come with another printing technology to print the sensors," says Sébastien Lani, project manager at the Swiss Centre for Electronics and Microtechnology (CSEM), which runs SWaP in partnership with CERN.

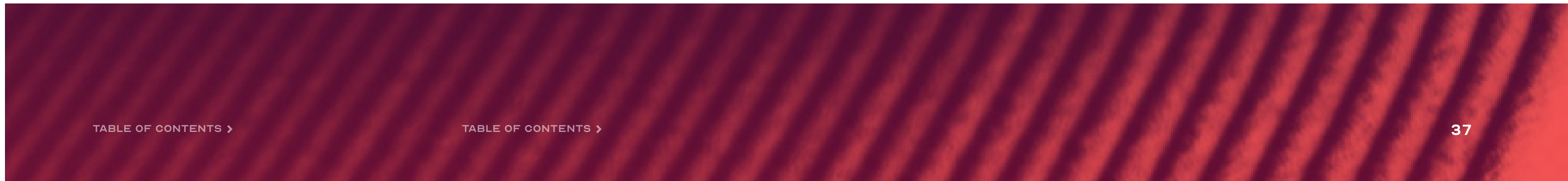
The cooling systems in the latter's Large Hadron Collider use a lot of components, which means they take up "a lot of space and weight," adds Lani. "With our technology, the objective was not only to make a pipe with sensors, but also to reduce the mass, to reduce the number of assemblies, and to make the life of everyone easier," he explains.

ADVANCED X-RAYS FOR BETTER 3D PRINTING

DM-DX is investigating an advanced form of X-ray imaging to improve Laser Additive Manufacturing (LAM), which enables 3D printing of structurally complex metal components by liquifying and mixing solid substrates. LAM is prone to error because scientists don't yet know enough about the internal physics of the alloys being created, so the DM-DX researchers want to peer inside them using x-rays.

Standard x-ray machines, such as those used in hospitals, create an image based on whether or not a surface reflects the rays back. But the DM-DX researchers are working on phase-contrast x-ray imaging, which detects changes in the speed of x-rays passing through a material, providing more detailed information about the nature of whatever is being scanned. They aim to develop a phase contrast imaging system that can scan the internal structures of alloys printed using LAM printers, in order to find new ways to prevent flaws.

DM-DX is a joint effort between University College London, German firm Microworks, and Diamond Light Source. Diamond is the UK's national synchrotron light source, which produces electromagnetic radiation using a circular particle accelerator.



PRINTING WEARABLE SENSORS

The 3D-MIPS project, run by the University of Northumbria and Swiss firm Magnes, is using 3D printers to create wearable sensors for monitoring purposes. The 3D printed materials serve as a base for arrays of piezoelectric sensors, which can turn heat and pressure into an electric signal.

TRANSFORMING THE DELICATE TASK OF BUILDING SCINTILLATORS

The 3DSCINT project aims to simplify the laborious task of assembling the delicate and costly materials used to make scintillators, which detect subatomic particles. Normally, manufacturers "have to painstakingly glue fibre after fibre next to each other," explains David Deganello, professor of engineering at Swansea University.

3DSCINT uses 3D printers to create a polymer scaffold into which the scintillating fibres can be threaded, which makes assembling them "a few minutes job, not a six months job like before," says Deganello. The project also involves printing the casings to protect the materials.

The researchers at Swansea University and Glasgow-based firm Lynkeos are developing scintillators that detect muons, tiny elementary particles that are similar to electrons, but heavier. Small amounts of muons are present in sunlight, so they can be used to study the insides of structures and materials without using a particle emitter—though the process can take several hours due to the scarcity of the muons. In 2017, a muon detector was used to locate a secret hidden chamber in the Great Pyramid of Giza.

TOPIC COMMUNICATIONS

COMING SOON TO YOUR SMARTPHONE: PERSONAL RADAR AND DYNAMIC MAPS

Imagine a radar app on your smartphone that could quickly generate a dynamic map of whatever building you find yourself in, and show you where you are and how people are moving around you.

That's what researchers at the University of Bologna and the French Alternative Energies and Atomic Energy Commission (CEA) are developing in the PRIMELOC project. The dawn of 6G – the next generation of cellular technologies - could make it a reality in the next decade, according to Davide Dadari, associate professor of electrical engineering at Bologna.

Personal radar is one of the possible outcomes. The idea is that indoor maps hosted in the cloud would be constantly updated as personal radar users scan their surroundings, enabling people to see immediately which shops are crowded, for example. "Outdoors, you have Google Maps," says Dadari, principal investigator. "The challenge is to achieve what we are currently doing today with the outdoor scenario," he says.

CARS THAT CAN SEE THROUGH FOG

The SINATRA project aims to develop a radar that can help self-driving cars "see" in dense fog. Self-driving cars detect objects using cameras and image recognition software, which—like human vision—are impaired when visibility is poor. That's not a problem for radar, but precisely tracking the direction of fast-moving objects with radar currently requires expensive, military-grade antennas that aren't suitable for a civilian car.

That's why the SINATRA researchers are designing advanced direction-tracking antennas that can be cheaply integrated into printed circuit boards (PCBs). SINATRA is a joint effort between the University of Siena and ECM, an Italian company that makes electrical equipment for railways, and the project is also looking at ways to use the technology to detect people and obstacles on level crossings.

LIGHTING THAT CAN DETECT FALLS

The VLADIMIR project is exploring safety applications for visible light communication (VLC). VLC is a method of transmitting information through room lighting by using LED bulbs that pulse at a rate humans don't notice—making it a possible substitute for WiFI, among other things. But VLADMIR is looking at how the technology could be used to detect when someone falls over without the need for intrusive cameras, by measuring shifts in reflected light as people and objects move around the room.

"If a person stands between the LED and the photodetector, he will create a shadow," says principal investigator Alexis Dowhuszko, "this shadow will have a specific kind of signature that will depend on the object that is creating that shadow." The goal is to develop a system sophisticated enough to identify objects and their movements, says Dowhuszko, a senior researcher at the Centre Tecnològic de Telecomunicacions de Catalunya (CTTC), which is running VLADIMIR in partnership with Aalto University in Finland.

COUNTING PHOTONS

Gisiphod (adapted from "GHz single photon detector") aims to demonstrate how fibre optic networks could be made more efficient by increasing the rate at which light pulses of just a one photon can be counted. Fibre optic communications networks use photon detectors to count light pulses of different durations, and the patterns of those pulses translate into data. Making the pulses faster means more data can be transferred in less time.

However, there's a trade-off with power consumption: to count the shortest pulses accurately at the highest speeds, today's detectors need at least 1,000 photons in each pulse, which requires a lot of energy. Cutting-edge detectors can count just one photon at a time, but not at speeds suitable for today's telecommunications.

MAKING COMPUTER MEMORY MORE ROBUST

ULTRARAM is an effort to develop a new kind of random-access memory (RAM) for use in the Internet of Things (IoT), where various objects are fitted with connected sensors and devices. RAM is fast, temporary memory that computers use to store only what they need immediately. When the power is cut, the RAM gets wiped, which makes it "volatile" memory.

But many IoT outdoor devices will have unreliable power sources, such as tiny solar panels. With volatile memory, if the power fails in the middle of an operation, the device has to start all over again when the power comes back on. If it's a sensor that's collecting and processing information, the data could be lost entirely.

MAKING USE OF COLD CHIPS

The LIGHTNING project aims to develop a way to connect super-fast rapid single flux quantum (RSFQ) chips to optical communications networks. RSFQ technology enables fast data processing with very low power consumption, but the chips only work at 4 degrees Kelvin, or minus 269 degrees Celsius, which means they can't simply be plugged into a regular network.

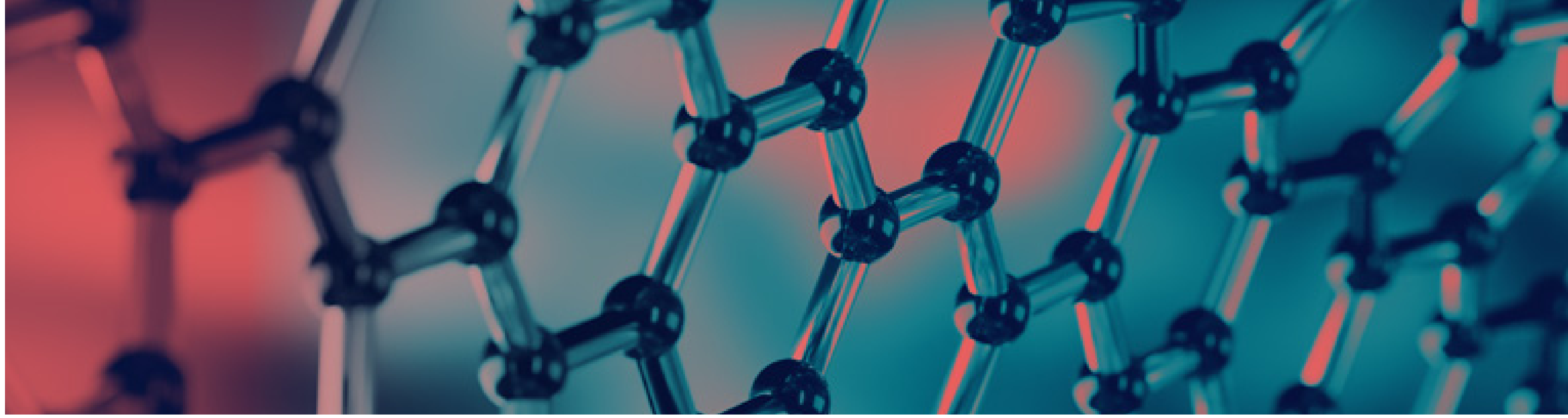
The researchers are developing a photodiode that can operate at this temperature and convert electrical signals from the RSFQ into light, allowing the data to be transmitted to a network running at ordinary temperatures. LIGHTNING is a partnership between the University of Tampere, the University of South-Eastern Norway, and the VTT Technical Research Centre of Finland.

SILICON PHOTONICS FOR SMALL SATELLITES

The SiPhoSpace project is developing silicon photonics circuits to be used in small, low-earth orbit satellites, such as the Starlink satellite constellation being built by SpaceX, that may one day provide high-speed wireless internet in remote areas. SiPhoSpace is led by CERN in partnership with Italy's National Institute of Nuclear Physics, the Karlsruhe Institute of Technology, and the University of Bristol.

Silicon photonics aim to do for microchips what fibre optics have done for cables: replace electrical signals with light pulses that transmit data faster, consume less power, and resist electromagnetic interference. But it's still early days for photonic chips, because engineering silicon to emit light is complicated, while alternative materials are either too costly or just not practical. For example, the lasers that beam light into fibre optic cables are often made with relatively rare elements like indium, and the cables themselves are glass.

TOPIC GRAPHENE



USING GRAPHENE TO DETECT MALARIA

The MULTIMAL project is developing a small device that can be used to rapidly identify malaria parasites using saliva samples, without the need for lab equipment.

Today's portable malaria testing kits, often used in remote areas with limited medical infrastructure, are "just above flipping a coin," because they are right only 60 per cent of the time, says MULTIMAL principal investigator Jérôme Bôrme. The disease, which the World Health Organisation says killed 435,000 people in 2017 (nearly all of them in Africa), is caused by five species of parasite that can be easily identified in a lab. But treating the disease in remote towns and villages is difficult because of the lack of reliable portable testing kits, explains Bôrme, MULTIMAL's principal investigator and staff researcher at the International Iberian Nanotechnology Laboratory in Portugal, which runs MULTIMAL in collaboration with the University of Minho.

Existing tests use a surface that changes colour when exposed to blood containing anti-malarial antibodies created by an infected patient's immune system. But MULTIMAL aims to identify traces of the parasite itself using graphene: an extremely strong material made from atom-thin layers of carbon arranged in a lattice—like a honeycomb—that conducts electricity differently depending on the molecules its surface is exposed to. The researchers hope that by detecting the electrical "signature" of the malaria parasite on graphene, they will be able to improve the effectiveness of field tests.

LOW-POWER, HIGH-RES DISPLAYS

GIMOD aims to develop low-power, high-visibility, high-resolution, high-frame-rate and high-colour displays using graphene pixels. This unique material reflects light in ways that make it ideal for use as pixels in display screens, notes Santiago Cartamil Bueno, GIMOD principal investigator and managing director of Estonia-based firm SCALE Nanotech.

Like the e-ink displays used in e-readers—and unlike those used in televisions, laptops or most smartphones—GIMOD's screens work by reflecting ambient light, which keeps power consumption low and means the display is still visible in harsh sunlight. Pieces of graphene move in tiny chambers, and their position within the cavity determines the colour reflected back. The graphene pixels can display far more colours than e-ink, according to Cartamil.

Because the graphene pixels are so tiny, the resolution is extremely high—up to 2,500 dots per inch (DPI). By comparison, a 40-inch high definition TV supports 55 DPI, and the Sony Xperia 1 II—currently the world's highest-resolution smartphone—supports 644 DPI. The pixels can also change colour very quickly, allowing smoother moving images: GIMOD is aiming for refresh rates of up to 400Hz (400 changes per second): top-of-the-range household TVs can manage barely more than half that, while Netflix runs at 60Hz.

SUPER SENSITIVE LIGHT SENSORS

The NanoUV project is using carbon nanotubes—hollow tubes of graphene with microscopic diameters—to improve ultraviolet (UV) light sensors, or photodetectors.

The project exploits the photoelectric effect, the discovery of which won Albert Einstein the Nobel prize: when electromagnetic radiation, such as photons of UV light, hit a surface, electrons are released. In principle, measuring the electrons means measuring the photons, which is what photodetectors do. But when the incoming light is very faint, the difficulty is finding a surface that doesn't reabsorb too many electrons before they can be measured. That's where the carbon nanotubes come in.

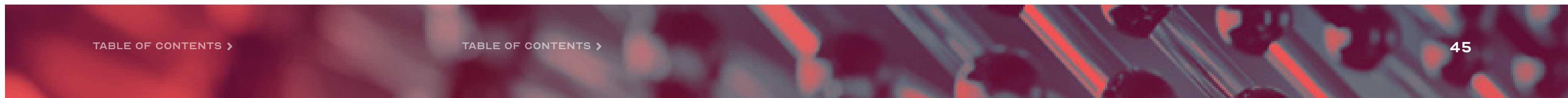
As electrons are reabsorbed into the materials, typical UV light detectors are only about 20-25 per cent efficient in detecting individual photons, and 35 per cent is considered extremely good, explains Francesco Pandolfi, NanoUV principal investigator and staff research at the INFN. The NanoUV researchers hope graphene will improve detector efficiency by having the electrons pass through the empty space inside bundles of carbon nanotubes kept in a vacuum, instead of through solid material, minimising reabsorption. The electrons then hit silicon, where they form a current that can be measured. If NanoUV can double the efficiency, "then you would need half the amount of light to make the same precise measurement," notes Pandolfi.

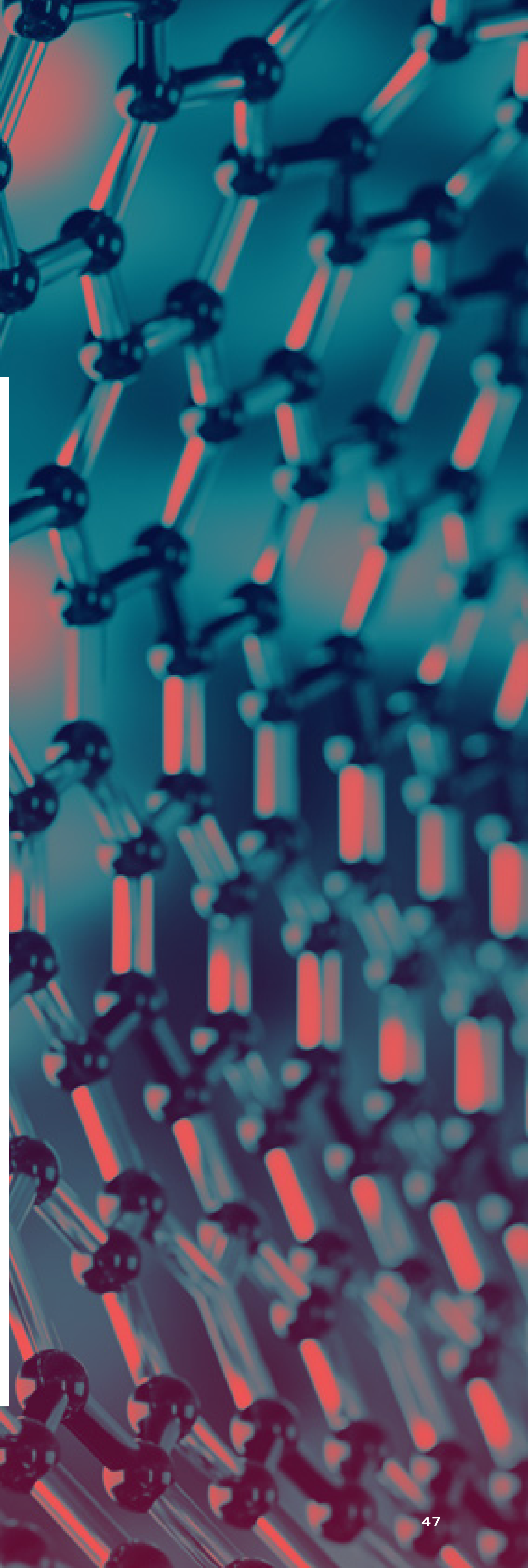
EXPANDING THE CAPABILITIES OF PHOTODETECTORS

In BANDPASS, Romanian researchers are using graphene to create photodetectors that can detect a much broader range of the electromagnetic spectrum than those on the market today, reducing the need for multiple devices made from different materials. A graphene compound called reduced graphene oxide is dispersed in a liquid solution, forming a film, and tiny nanoparticles of carbon are placed on top. When the light hits this surface, the photoelectric effect kicks-in and the electrons are passed to a metal conductor.

The goal of BANDPASS is to develop a photodetector that can detect all wavelengths from UV light (short wavelength) to near-infrared (long wavelength); visible light is in between the two. Current photodetectors cannot achieve that breadth.

The new grapheme-based material "can have a sensitivity to all these wavelengths at once," says Lucia Monica Veca, BANDPASS principal investigator and senior researcher at the National Institute for Research and Development in Microtechnologies (IMT) in Bucharest. "We don't need several materials, or different materials, to detect light at a certain wavelength. We have one material that can detect light for the whole spectrum, from ultraviolet to near-infrared."





INTEGRATING PHOTODETECTORS INTO SILICON ELECTRONICS

In the REVEAL project, the Institute for Microelectronics and Microsystems of Italy's National Research Council (CNR) is working with Italian firm Micro Photon Devices to come up with a new method for integrating graphene-based near-infrared photodetectors into silicon-based electronics.

Silicon-based photodetectors can't pick up near-infrared light because silicon is transparent at wavelengths longer than visible light. There are compounds that do work and are used in fibre-optic communications, such as indium phosphide, but they're not fully compatible with silicon-based electronics. Graphene has shown some promise as a substitute, but current designs aren't efficient enough to make it viable for industrial use. REVEAL aims to solve the problem with a new process that improves on existing methods.

BUILDING LOW-COST TERAHERTZ DETECTORS

The GRANT project is using graphene to create small, low-cost THz detectors, which could be used, for example, by drones to survey bridges, railways and other infrastructure, or to monitor crops. GRANT's sensors convert the electromagnetic energy into heat, which alters the shape of a thin membrane in ways that can be read by a laser, like a CD. Researchers at three institutions are contributing to GRANT: The Institute of Materials and the Institute of Nanoscience, both part of CNR, and the Elletra Sincrotrone research centre in Trieste.

MINIATURISING SPACE TELESCOPES

The ROTOR project aims to use graphene to help study the universe. Some telescopes pick-up wavelengths in the high-frequency terahertz (THz) spectrum—which is between infrared light and microwaves—in order to peer deep into the universe and draw conclusions about its history. But because the Earth's atmosphere blocks THz waves, the large telescopes either need to be built at high altitude or launched into space, which is very costly.

By using graphene, ROTOR aims to develop much smaller and lighter THz sensors that can resist ambient radiation, allowing them to be used in space with the same sensitivity as large telescopes. The researchers at the University of Eastern Finland, the Belarussian State University and the University of Salerno also foresee potential applications on Earth, such as inspecting food and identifying chemicals, since terrestrial substances also have THz "fingerprints."

ATTRACT

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