FETFX

VOICES FROM THE FUTURE

30 YEARS OF BREAKTHROUGH TECHNOLOGIES IN EUROPE

«Technology influences science but it is a bidirectional relationship. Programmes such as FET are important because they require us to think far ahead.»

PROF. EDVARD I. MOSER
Nobel Prize in Physiology or Medicine awarded in 2014
Coordinator of GRIDMAP FET project

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Foreword

THOMAS SKORDAS
Director "Digital Excellence and Science Infrastructure"
Directorate General for Communications Networks, Content and Technology (DG CONNECT)

Future and Emerging Technologies (FET) has been part of the EU's research programmes for over 30 years. It has proven to be one of the most visionary, ambitious and inspiring programmes addressing the technologies of the future. Over the years, it has nurtured multiple innovations and breakthroughs. It has brought together Europe's most creative, curious and passionate minds, from young researchers to Nobel Prize winners, all working together to keep Europe at the forefront of scientific leadership and technological innovation.

FET is a unique research programme within the European research funding landscape. Its uniqueness is due to its emphasis on novelty, interdisciplinarity, risk and collaboration, as well as its specific focus on advanced technology and application relevance. There are numerous areas where FET has contributed to Europe's scientific leadership, including quantum computing and communications, nano-electronics, neuro- and bio- information science, advanced robotics, new forms of man-machine interaction, including brain interfaces, and complex systems. A number of successful mainstream research programmes launched in the past few years across Europe would not have taken place without the pioneering efforts of FET.

FET has contributed to paradigm shifts: technologies that once seemed the stuff of science fiction are now becoming or about to becoming everyday reality, such as real-time translation, intelligent robots, personalized medicine, opto-genetic technologies in neuroscience and artificial memory implants.

Being part of a FET project is often a transformative experience for researchers. Of all comparable programmes, FET has the highest rate of interdisciplinary publications, both in terms of authorship and readership. In a typical FET project, different disciplines do not just complement each other, but cross-fertilise to create entirely new areas of investigation, often with unexpected results. Many participants have built their career on these, for instance through subsequent ERC grants, by founding new research groups, or by creating their own deep-tech exploitation path.

I am convinced that the success and the evolution of FET have been and continue to be a unique experience. This booklet provides a snapshot of the first 30 years of FET. It explains the evolution of the programme, through testimonials of some of the people who shaped its policy aspects, examples of projects and their impact on technology and economy, and profiles of FET researchers, who have been listening out for "voices from the future".

The FET story is not over, however. Today, on the eve of Horizon Europe, the next EU Framework programme for research and innovation, most of FET is being integrated into the Enhanced European Innovation Council (EIC) Pilot: specifically, as the EIC Pathfinder, the new home for deep-tech research and innovation in Horizon 2020 and Horizon Europe.

By bringing together the worlds of research and innovation within a single programme, the EIC will provide FET with an exciting next stage in its existence, and new opportunities to enhance its impact. The EIC Pathfinder programme will continue supporting new and emerging topics that will shape the future technology landscape. In addition, by detecting new and promising technologies at an early stage, it will be possible to accelerate their development and speed up their move to market, with the help of the access to market creation and scale-up mechanisms offered by the downstream-oriented part of the EIC, the Accelerator programme.

I am sure that the FET programme's three decades of experiences will be an excellent asset to the European Innovation Council's activities, giving scientific research and disruptive ideas a chance to become breakthrough technologies and to change people's lives more quickly than ever before.

I am confident that even more will come from the EIC Pathfinder.

Enjoy the reading!

Introduction

MARTA CALDERARO
FETFX Project Coordinator, H2020 FET National Contact Point

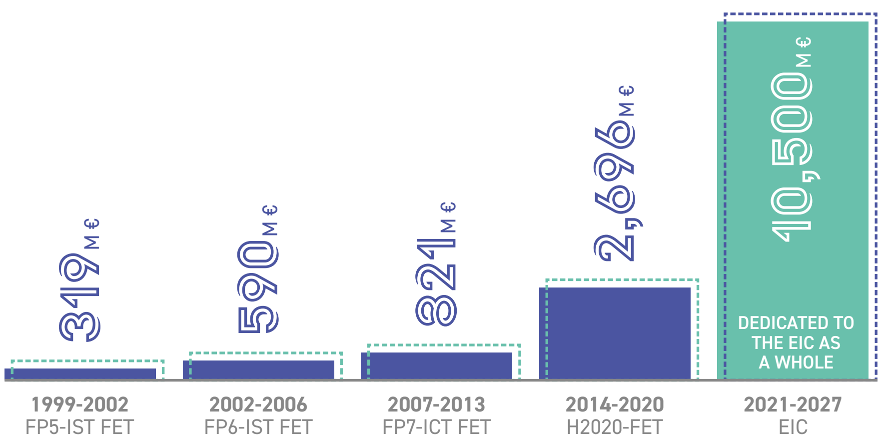
For 30 years, the Future and Emerging Technologies (FET) programme encouraged the European research and innovation community to establish and consolidate the most promising next-generation technologies of the future.

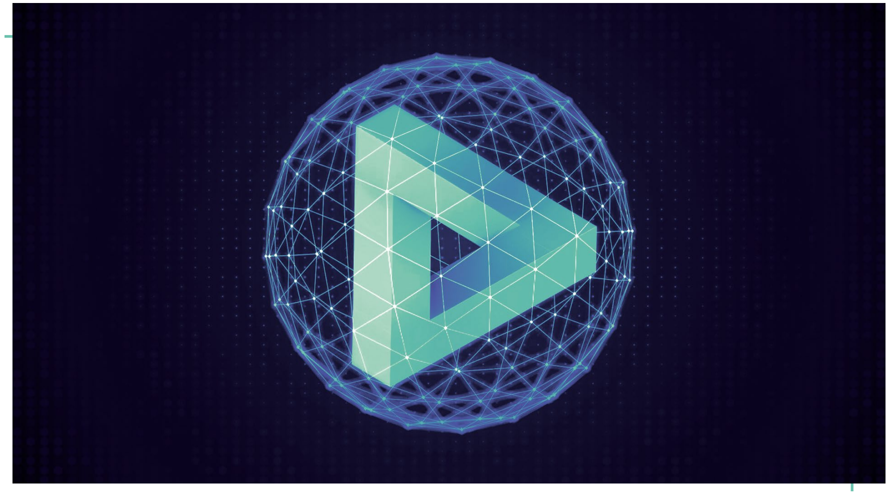
The programme evolved into what's known as a seed for the European Innovation Council (EIC) and its Pathfinder for Advanced Research. It envisaged its main elements as drivers for Europe's future economic well-being, prosperity, and competitiveness.

This booklet produced by FETFX will lay out Europe's path towards emerging technologies during the past three decades. Readers will discover the policy evolution, the game-changing innovation and the scientific discoveries that took place.

To date, Horizon 2020 FET programme supported more than 412 grants with about 3.847 beneficiaries, of which 14% is represented by SMEs. More than 4.4 Billion euros has been allocated to financially support Pathfinder-like schemes. This has been distributed through the years to push technological boundaries and to support science-driven deep-tech. Until now, about 10 Nobel Prize winners participated in this unique mix of high-risk, long-term, multidisciplinary and collaborative frontier research projects. The EIC Advisory Board, recently published its vision calling for a €10 billion budget dedicated to the EIC Pathfinder and Accelerator, to crowd in €30-50 billion impact.

European financial support on Pathfinder-like schemes





You will also find in this booklet information on the major novelties introduced in FET-like funded programmes, its timeline, as well as the evolution and the genealogy of FET Proactive, which include today's most disruptive innovations in quantum technology, neuroscience or bio- and nano-technologies in Europe.

Outstanding interviews will give us profound insights about the European funding programme (Simon Bensasson), its relation with National research priorities (Dr. Corda), and a look at its future as EIC Pathfinder for Advanced Research (Prof. Langer).

Europe is the best place for researchers and innovators to develop their potential and realise their dreams

Emerging technologies and cutting-edge research will be explored as this booklet contains stories that describe their major impacts on innovation and the market, and on careers and technological trends. Experiences in FET from a revolutionary scientist as Prof. Paolo Dario - founder of The BioRobotics Institute of the Sant' Anna School of Advanced Studies - and a talented innovator, Ana Maiques – winner of the Women Innovator Prize - will be provided.

The EIC Advisory Board often tell us, "Europe is the best place for [researchers and innovators] to develop their potential and realise their dreams and ambitions [in paradigm- changing ideas]".

Join FETFX on this journey to discover just some of the visionary achievements made by FET and EIC Pathfinder projects in recent years.

FET PROGRAMME EVOLUTION

1988

FIRST FET-LIKE SCHEME INTRODUCED UNDER ESPRIT2 PROGRAMME

Unconventional and visionary inter-disciplinary research with potential industrial impact was supported under ESPRIT2, ESPRIT3, ESPRIT4, FP5 IST, FP6 IST, FP7 ICT Programmes, in the field of "Information technologies".

2007

FET CALLS INTRODUCED IN FP7 COOPERATION

FET proposals on ICT and energy were officially announced. These radical breakthroughs were expected to break conventional boundaries in scientific disciplines.

2009

DEFINING A STRATEGY FOR RESEARCH ON FET IN EUROPE

A communication from the Commission to the European Parliament was released. It identified the scope and ambition of the two complementary FET schemes namely, FET Open and FET Proactive.

2010

ADDRESSING HIGH-TECH SMES AND YOUNG RESEARCHERS IN FET RESEARCH

FET recognised the value of having young researchers and high-tech research-intensive SMEs on board and thus integrated them in the FP7 ICT Work Programme 2011-12.

2011

TALKS OF A EUROPEAN HIGH-RISK INNOVATION COUNCIL

The idea of the EIC was first presented at the FET European Future Technologies Conference and Exhibition.

2013

FET FLAGSHIPS LAUNCHED

Major large-scale research initiatives were presented: Graphene Flagship, Human Brain Project followed by Quantum Flagship (2016) and the New Battery 2030+ initiative (2018).

2014

FET IN HORIZON 2020 WITH A NEW LEVEL OF AMBITION

The mission of FET under Horizon 2020 was to turn Europe's excellent science base into a competitive advantage by uncovering radically new technological possibilities, beyond Information and Communication Technlogies.

2015

FET PRINCIPLES INCUBATED IN EIC

FET Advisory Group published "the Future of FET", which declared the opportunities FET provides in research-based innovation.

2016

COMMISSIONER MOEDAS LAUNCHED THE EIC

While Europe seeks to be a future leader in start-ups and scale-up initiatives, the European Commission's DG RTD called for stakeholders' view of its innovation landscape – a precursor to the EIC.

2017

EIC'S INDEPENDENT HIGH-LEVEL GROUP OF INNOVATORS FORMED

Publishing "Europe is open for innovation", they recommended the EIC to support breakthrough innovation for everyone's benefit including those involved in start-ups and scale-ups across the EU.

2018

EIC PILOT PHASE OFFICIALLY BEGAN

The EC launched the EIC Pilot phase with FET Open and Proactive now part of EIC Pathfinder, assembled its Advisory Board and released an independent report on accelerating innovations.

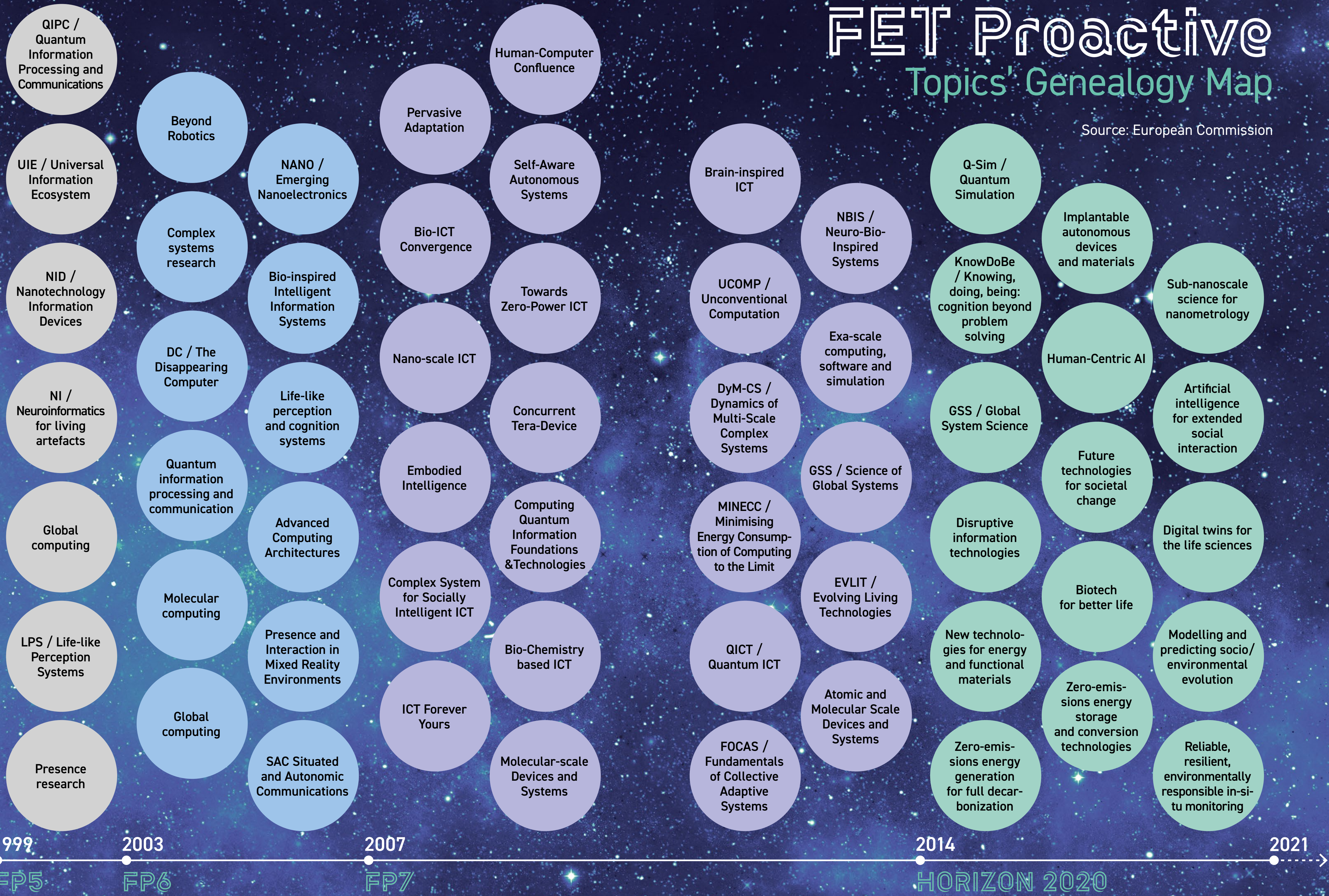
FROM 2021

EIC UP AND RUNNING IN HORIZON EUROPE

The EIC will meet Europe's need to capitalise science in global markets by turning it into new business opportunities and by accelerating the scale-up of "game-changing" innovation shaping our future.

FET Proactive
Topics' Genealogy Map

Source: European Commission



BREAKTHROUGHS IN NUMBERS

Figure 1

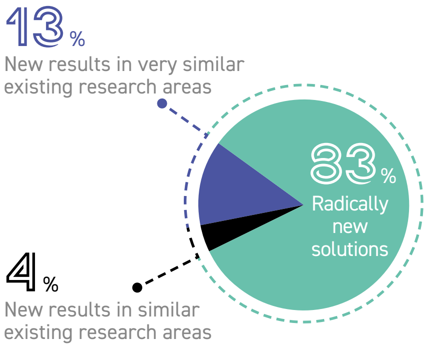


Figure 2

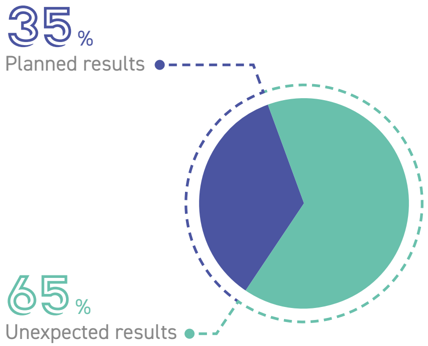


Figure 3

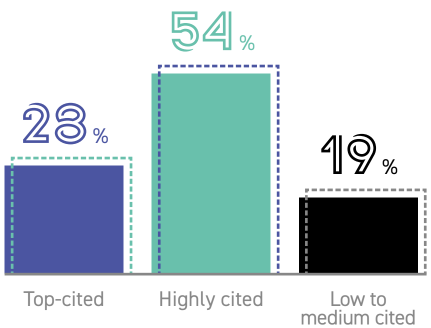
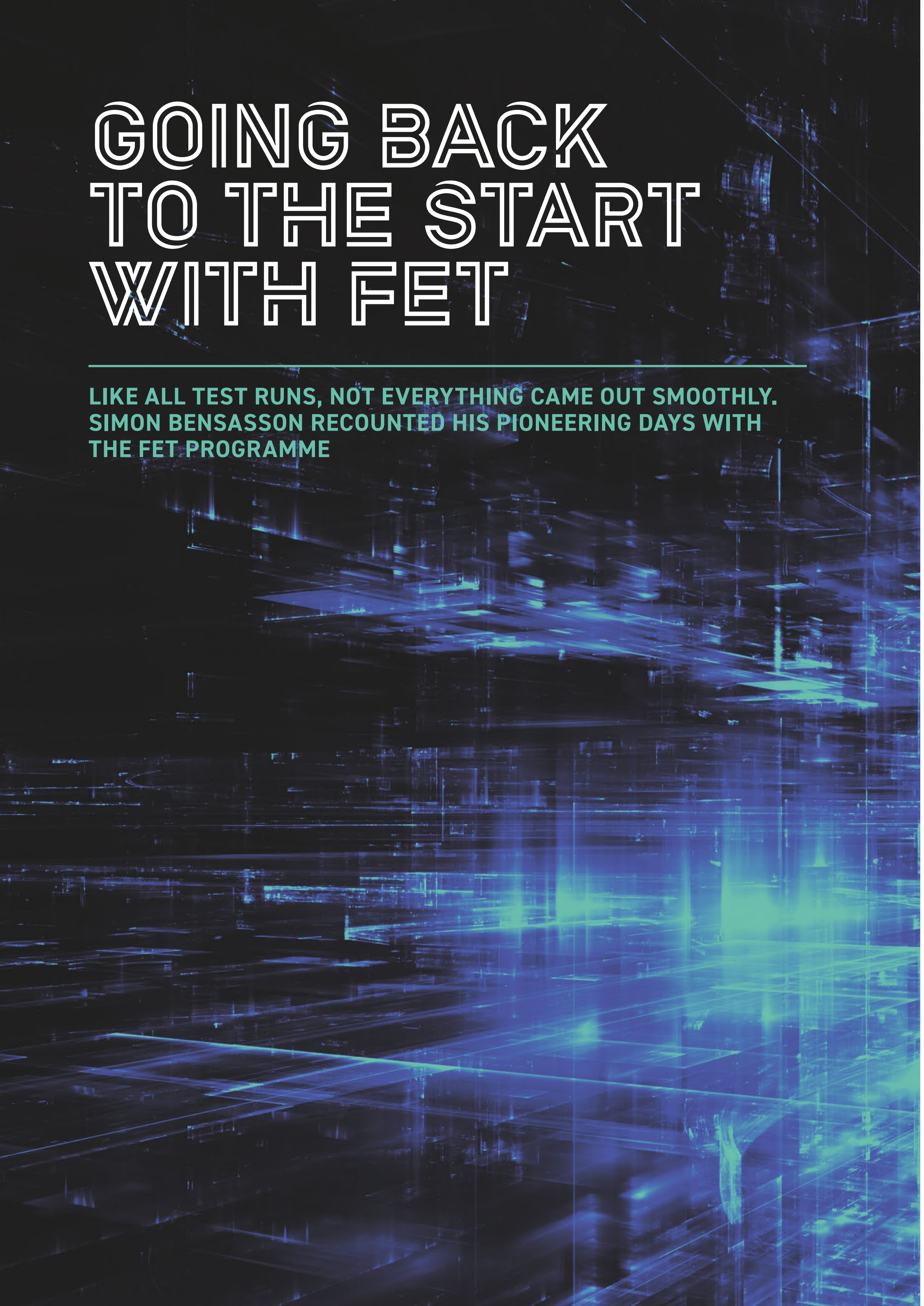


Figure 4

FET has a unique role as a bridge between science and innovation. A recent study, *FET_Traces* assessed the impact of 224 finished FET Open and FET Proactive projects. Results from FET projects are novel (fig. 1), unpredictable (fig. 2) and produce high quality interdisciplinary publications (fig. 3).
Participating in a FET project promotes careers, opens new interdisciplinary collaborations, and lets researchers branch out into entirely new research directions, often changing their career path (fig. 4).

REFLECTIONS ON POLICIES THAT SHAPED FET

FET DID NOT MATERIALISE OVERNIGHT. DISCOVER THE DIFFERENT STORIES THAT RECOUNT THE METAMORPHOSES OF FET AT A POLITICAL CONTEXT THROUGH THE EYES OF EMINENT LEADERS ☞



GOING BACK TO THE START WITH FET

LIKE ALL TEST RUNS, NOT EVERYTHING CAME OUT SMOOTHLY. SIMON BENSASSON RECOUNTED HIS PIONEERING DAYS WITH THE FET PROGRAMME

Simon Bensasson was the FET Head of Unit in FP4 and FP5. In a broad career that has spanned entrepreneur to senior public servant and academic, he shares memories from the heady days at the start of the FET programme.

What were the early days like managing FET?

We were aware that we were breaking new ground. We saw good practices in national programmes and in other countries such as the US, but we knew that cooperative research at the European level would inevitably be different. We were making changes which we considered as solutions that addressed the difficulties, and were fully aware of it. This made for a very "heady" pioneering feeling.

What were the difficulties?

We all agreed that advanced research should be open to new ideas. We also all agreed that research should focus on areas that show promise and where there is local strength that can lead in breakthroughs. Unfortunately, these two requirements contradict each other: a programme can't be open and focused at the same time. Selection criteria to fit both purposes would ensure mediocrity through compromise rather than excellence satisfying none of the purposes.

How did you get around this issue?

Odd though it may sound today, the compromise approach was the norm from the first FP to the mid-to-late 90s when FET was established.

Calls were based on elaborate work programmes where they were almost pre-empting the nature of the research to be carried out. Our own motto came as a reaction to that: "If you know exactly what you want to do, forget it. It is too late".

How did these themes translate into specific research programmes?

SIMON BENSASSON

«We saw good practices in national programmes and in other countries such as the US, but we knew that cooperative research at the European level would inevitably be different»

We adopted two separate sets of selection criteria which resulted in two schemes: The FET-Open scheme placed absolutely no technological priorities – anything that could contribute to radical advancement in the state-of-the-art in ICTs (Information and Communication Technologies) was receivable. The FET-Proactive scheme focused on emerging technologies. A key aspect here was that the supported projects would be cooperating with each other and a network of excellence was set up to promote and coordinate such cooperation.

How did the two schemes relate to each other?

There was no allocation of budget between FET-Open and FET-Proactive. Funds would be allocated as a function of the quality of the research proposed by a strong team of 18 project officer (PO) scientists, supported by global level experts in their respective fields. Likewise, there were no specific FET-Open and POs, each officer was involved in both schemes.

How did you select the areas in which to launch proactive initiatives?

At any one time there were about 200 FET projects running, most of them in the Open scheme. The POs and scientists were in a position to detect patterns and opportunities. For example, detecting what was happening in the very broad area of photonics where we had many projects running led eventually to a proactive initiative on quantum computing. Observing work in micromechanical microsystems led to an initiative in nanoelectronics etc. Sometimes the transition from individual projects to an integrated initiative was preceded by setting up a Network of Excellence of all those able and willing to contribute to defining an initiative.

What were the specific challenges of the FET-Open programme?

The first problem was oversubscription. Being open to everything increased the population of potential participants. We "invented" the two-step proposal in the hope that if about two-thirds of proposals were rejected in a very easy first step (asking the "what?") and one-ninth accepted after the second step (evaluating the "how?") then the pain of the oversubscription would be diminished. This two-step proposal was received enthusiastically by the research community and later adopted in other parts of European research programmes.

And what didn't work?

Things of course rarely go entirely to plan. FET is meant to open new ground and you never know what obstacles will be found – discovery is like that. It was also deemed better to abandon a project and spend talent in new ones rather than wasting it. This we failed to impose. We set a target of at least 10% failure of our projects each year on the basis that research as advanced as FET cannot always be successful.

Nevertheless, we always insisted that projects should have a goal: a kind of "man in the moon" vision, but also that they should be ready to abandon it if the research carried out pointed them to a different, better and more feasible one.

CHANGING THE RESEARCH LANDSCAPE WITH FET

BEING THE H2020 NATIONAL DELEGATE FOR FET, DR. DANIELA CORDA TELLS US HER EXPERIENCE IN SCIENCE POLICY, AND HOW THIS INFLUENCES THE WAY WE BUILD RESEARCH AND INNOVATION ECOSYSTEMS BOTH AT A NATIONAL LEVEL AND A EUROPEAN LEVEL

Dr Daniela Corda is permanent member of the European Molecular Biology Organization (EMBO) and Academia Europaea. As well as an active cell biologist, she has served as a member of several international advisory boards and selection committees, including the European Research Council (ERC) and the Federation of the European Biochemical Societies (FEBS) among others. She is a member of the genSET Science Leaders Panel, and currently the Delegate of Italy for Horizon 2020 (ERC, MSCA, FET Configurations) of the European Commission as well as CoChair of the Board of Funders for the FLAGERA program (FET-H2020).

As a H2020 National Delegate for FET, can you describe how this role works into the FET research landscape?

FET has been a successful programme, articulated in the FET Open, Proactive and Flagship programmes. Each programme has requested a specific interaction with the national scientific community: FET Proactive for example, has required a collection of information to bring to the FET Programme Committee the main areas of interest of our Member State, in my case Italy. This has been important to facilitate the Italian participation in the program. FET Open has seen an important participation and success of the Italian community, thus as delegate I have tried to promote (and obtain more funds for) this specific program. The construction of the Flagships has involved again the delegation both in the preparatory actions and in the ERA-NET funding and managing, also through the activity of the Board of Funders.

What is the best thing about being a National Delegate?

Well, as an active scientist, I have realised several years ago that science policy has to be part of our interests; it is also an important way to create links, a dialogue, between the scientific com-

Doctor
DANIELA CORDA

«I believe that to build an effective European Research Area, Europe has to become federation (at least for the development of research and innovation) with no borders»

munity and the policy makers. I have been involved in several ways in science policy, in recent years as Italian delegate. As such, I have enjoyed the interactions and friendship with other European delegates, colleagues across Europe, as well as the frequent contact with our scientific community and with members of the Italian Ministry of Education, University and Research (MIUR).

And the worst thing about being a National Delegate?

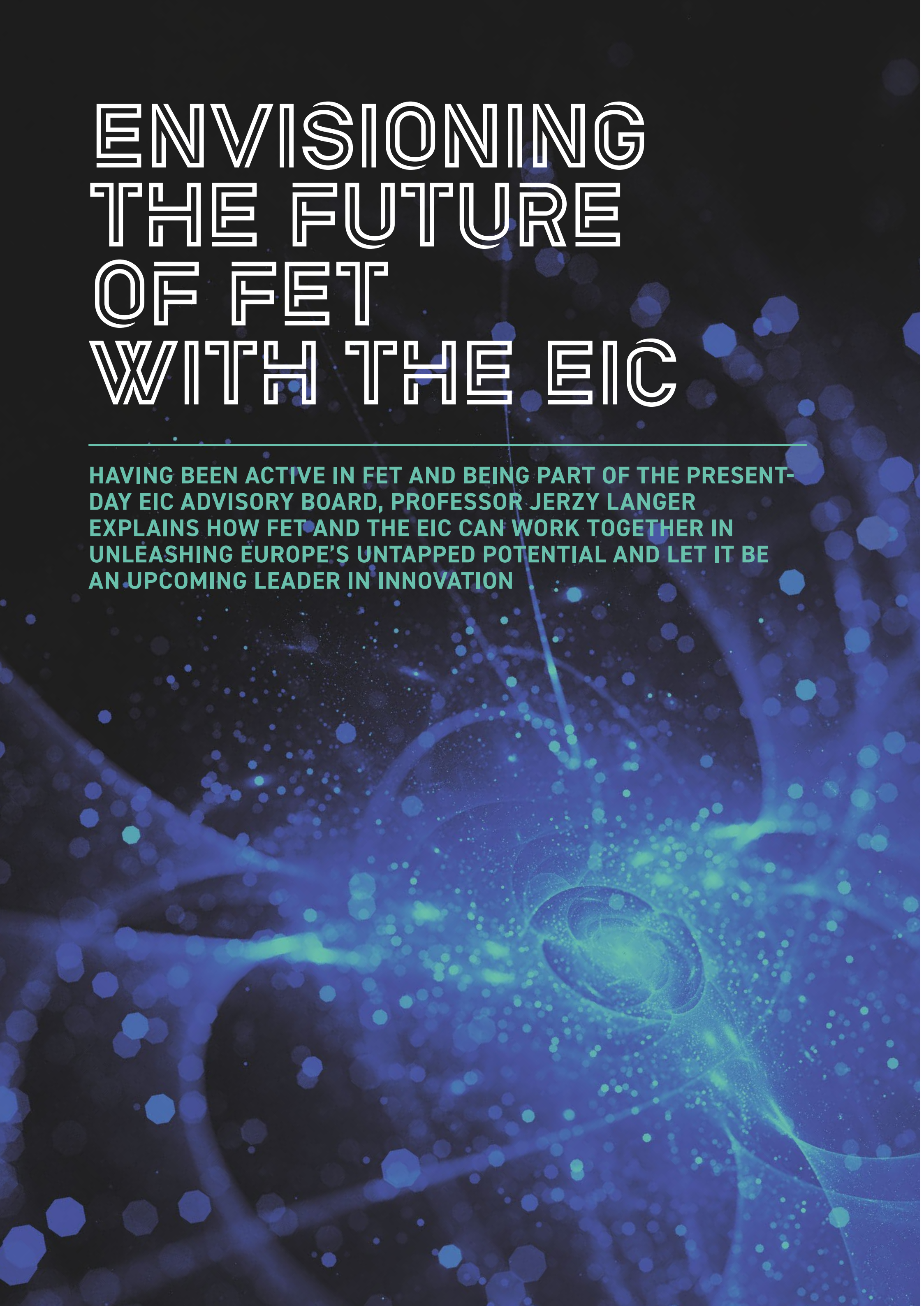
I usually enjoy what I do, thus I do not have specific criticisms. Certainly being a delegate requires dedication, and takes time, which I tried not to subtract from my scientific interests and my laboratory. I mostly spent my weekends preparing for the FET Programme Committee or answering emails and reading papers related to FET. As a consequence, my "free time" was much reduced, which sometime can be a burden.

How does your National Delegate work with the FET Flagships?

As a delegate I have contributed to several meetings in preparation for the Italian contribution to Flagships, in particular to the Human Brain Project. I have participated in the national meetings, then as elected co-chair of the BoF, I have organized together with the Commission the BoF meeting and discussed the organization (governance, calls etc) of the flagships. Last, together with colleagues at the MIUR I analyzed and presented the results of the consultations for new flagships, then followed by the definition of the six CSA that should identify future flagships (or similar actions) in Horizon Europe.

What would you like to see in the future of FET research and policy?

I believe that there are several actions discussed in the last decades, very important for the scientific community, but never really implemented. This is not specific to FET, but it affects all programmes. We have discussed about having the 'best-science' driven community, but the circulation of researchers in Europe is not easy at all. The "researcher visa" is still on its way, never really implemented. I believe that to build an effective European Research Area, Europe has to become a federation (at least for the development of research and innovation) with no borders, same laws for social security, retirement, family benefits, similar education and degree definition etc. I could quote other examples, but this is the Europe I wish to see one day, hopefully soon.



ENVISIONING THE FUTURE OF FET WITH THE EIC

HAVING BEEN ACTIVE IN FET AND BEING PART OF THE PRESENT-DAY EIC ADVISORY BOARD, PROFESSOR JERZY LANGER EXPLAINS HOW FET AND THE EIC CAN WORK TOGETHER IN UNLEASHING EUROPE'S UNTAPPED POTENTIAL AND LET IT BE AN UPCOMING LEADER IN INNOVATION

Professor Jerzy Langer, Emeritus Professor at the Institute of Physics of the Polish Academy of Sciences – EIC Advisory Board member. Langer has vast experience in pan-European organizations such as Academia Europaea, the ESF, Euroscience related to breakthrough science and innovation. Between 2015 and 2016 he acted as a FET-AG chair, coordinating analysis to underpin the EIC and the ERC.

Concerning the 'Future of FET' report drafted by the FET Advisory Board, why has FET been a seed for the EIC?

Europe is losing a competitive position in innovative technologies not only to the US but also to Asia. However, Europe has enormously large, still untapped but very dispersed, intellectual potential to attack most challenging issues of modern times. To do so, a concerted scientific and entrepreneurial activity in the field of developing and implementing breakthrough technologies is a must. None of the Member States can do so, but the European Commission has all the assets to play a pivotal role in unleashing this potential at European scale. In a nutshell, it is a mission of the EIC.

How has FET research fed into the actions of the EIC?

Over the years the FET has been a catalyst for phenomenal scientific and technological innovation, especially in the ICT. It was simple, non-bureaucratic, adaptive, goal oriented and most important – delivering at relatively low cost. It was also building an entrepreneurial community through collaboration across Europe, which is most critical. This why we, the FET Advisory Board (AB) so vigorously advocated to build the research leg of the EIC upon the FET experience.

What are the new challenges for the EIC Pathfinder programme?

Professor
JERZY LANGER

«The EIC has to become a seed of new deep-tech companies aspiring to become the world leaders and the technological unicorns»

The FET success was achieved mostly in the ICT field, which benefited so much on a rapid growth of semiconductor technologies and the explosive growth of informatics. But these miraculous technologies can open new avenues in other fields, like medicine and pharma, green technologies, manufacturing and finally AI – artificial intelligence. Hence, opening up the FET to these novel technological challenges through a novel Pathfinder instrument is a natural evolution, almost guaranteeing a success at large scale.

What are the obstacles to success for the European Innovation Council?

The key to success is a concerted approach, namely attacking not just interesting scientific problems, what is a domain of the ERC, but those which seek rapid practical solutions. And then constant monitoring in a way not letting to lose such an objective from sight – a common occurrence in a purely scientific community. This means a permanent checking of a possible developmental stage and a possibly to use the power of the second leg of the EIC, namely the Accelerator program. The EIC, therefore, must be seen not just as a more technology-oriented twin to the ERC – it has to become a seed of new deep-tech companies aspiring to become the world leaders and the technological unicorns.

What is your overall future vision for European FET research programmes?

There is a tendency to place innovators as prime clients of the EIC in contrast to the researchers-oriented ERC. But I hope to persuade both the business-based colleagues of the EIC Advisory Board and the Commission, that such a vision is not only short sighted but simply wrong. Pro-innovative research taken care of by the EIC Pathfinder and innovations supported by the Accelerator are just two sides of the coin and their separation would just kill the prime idea of the EIC – an EC offer to the most talented and entrepreneurial young Europeans – a fundament of the European New Deal and European Dream.

IMPACT ON INNOVATION AND MARKET

THANKS TO THE COLLABORATIVE EFFORTS BETWEEN RESEARCHERS, START-UPS AND SMES, FET HAS CREATED EMERGING TECHNOLOGIES THAT DISRUPTED MARKETS. LEARN MORE ABOUT THEM THROUGH OUR STORIES

THINKING LIKE PETER PARKER

SCIENTISTS ARE SPINNING UP ARTIFICIAL SILK FOR A PLASTIC-FREE FUTURE

We've all seen it before in comics, films and on TV – the arachnoid superhero who shoots webs to fight crime. Spiderman had been an iconic figure since he was first introduced by Stan Lee in the 1960s, but we know very little of the technologies used by our villain-catching superhero. As soon as he shoots out a web, he is able to seize criminals by the hand or stick them up to the ceiling. Was his web truly that strong? How much do we know about the silk's properties?

Silk is made out of natural protein biopolymer, which is only produced by spiders, silkworms and other arthropods. They use silk to build their cocoons and swaddling clothes for their offspring or to catch and to preserve their prey. We are able to take advantage of this natural fibre by removing the sericin or the outer protein coating of the silk, leaving the fibroin fibres that we use to weave into all sorts of clothes. With its exceptional strength, toughness and thermal stability due to its chemical nature, the silk used by Spiderman may have been good enough to toss one of his gross enemies out of the building.

As is often the case, science fiction seems less surreal. It's been a decade since the scientists put silks into good use other than weaving the most luxurious apparel in the market. Silks are biocompatible and biodegradable so researchers have used it in medicine, such as for tissue engineering and drug delivery, as well as in the field of optics, sensing and device miniaturization. But what if silk can also be used as an alternative to plastics?

Unfortunately, the path to upscaling these delicate fibres isn't as straightforward as it seems. Until now, many turn to breeding spiders or silkworms to gather as much silk fibre as possible. Our reliance to these creatures is what makes the production costly and unsustainable. What if there was a way to artificially produce or mimic silk fibres?

Nature has a funny way of doing things, which we have yet to learn. "Fibre formation in nature is energy optimized. If we want to have silk spun like a spider, we need to cut polymer fibre processing by over 90%," say Dr Chris Holland and his research group in a paper they published in Advanced Materials. Plastic processing as we know it makes use of temperatures intolerable for silkworms and spiders to handle. Moreover, the pipe flow used to in transferring fluid to tubes bears little resemblance to the creatures' biological nature.

High temperatures needed for polymer production today are not suitable for crafting silk-based materials

To answer all these, Dr Holland's team in the University of Sheffield together with seven partners from five countries formed FLIPT (Flow Induced Phase Transitions): a new low energy paradigm for polymer processing, a project funded by the EU FET programme. They will decipher nature's best kept secrets in producing silk and develop a low-energy system to create novel functionalised protein-based polymers called 'aquamelts'. With these biomimetic silks, they hope to spark a revolution and change the way we think about polymer processing.

The future of energy efficient high-performance polymer design has never been as fine as the silk woven clothes we use every day. Given the circumstances, time will only tell when someone can replicate Peter Parker's famous web shooter.

NEW "QUANTUM SORTER" PROVIDES INFO AT THE ATOMIC SCALE

RADICAL TECHNIQUES IN ELECTRON MICROSCOPY COULD REVOLUTIONISE STUDIES IN PHYSICS, BIOCHEMISTRY, MATERIALS AND MORE

For decades scientists, art-science aficionados and the wider public have marvelled at the beautiful worlds revealed by electron microscopy, from the hideous beauty of an insect's mouthparts to the shimmering world of meta-materials at the molecular level.

Modern machines can now fire powerful electron beams to produce images with single-atom resolution. But electron microscopes are much more than simple imagers. Probing properties like the composition of a sample or its magnetic properties, their flexibility as tools of investigation has made them precious allies for testing fundamental physics.

But electron microscopy is not without problems for scientists to fix. One important issue is that electron beams can damage samples as they strike them. This so-called 'dose problem' is particularly serious when the sample is very delicate, like a protein for example. When imaging samples, the dose problem forces scientists to seek an awkward trade-off between resolution and sample integrity.

A new European project, Q-SORT, is attempting to develop radically new techniques to explore and study fragile specimens at the microscopic level, uncovering an array of information that was previously hidden. Q-SORT exploits TEM (transmission electron microscopy), a technique in which a beam of electrons is passed through an ultra-thin slice of specimen to form an enlarged image.

Unlike previous incarnations of this technology, Q-SORT leverages the recently-acquired capacity to structure electron beams, turning the TEM into what project scientists call a 'quantum state sorter' or 'quantum sorter'. These sorters can probe the properties of samples with very few electrons, allowing scientists to answer tricky questions about the specimens with maximum efficiency and extremely low damage.

This careful specimen handling is key in research fields like biology and biochemistry that typically feature delicate samples. In cryomicroscopy for example, a technique where a flash-frozen specimen is fed into an electron microscope, the techniques developed by Q-SORT can be used to recognise protein structures, symmetries and orientations. These proteins can be cell-signalling molecules, or parts of membranes, which ultimately provide us with knowledge of how cells and tissues function. Progress in the development of cryomicroscopy led to the Nobel Prize for Chemistry in 2017.

The new information gathered from quantum sorting could eventually be applicable in drug design for healthcare and next-generation biomedicine. What's more, the quantum sorter is a multipurpose tool which will be useful in many other fields besides biochemistry. For example, control of the information extracted by electrons from certain specimens could allow researchers to clarify many important physical mechanisms, such as those underpinning magnetic spin properties, or the physics of plasmons.

As project leader Vincenzo Grillo said: "We believe that the quantum sorter will become so important that it will eventually be part of every state-of-the-art TEM, since the new technology is easy to integrate with energy-loss spectrometry."

Q-SORT is funded by a €3 million grant by the European Commission's FET programme.

Cryomicroscopy is a branch of miscroscopy which can be used to better understand the structure of complex molecules such as proteins

Photo: Sicco van Grieken, Eindhoven University of Technology

LIGHT-EMITTING SILICON: NO LONGER A "HOLY GRAIL" FOR COMPUTING

IF COMPUTERS TRANSMITTED DATA USING PHOTONS INSTEAD OF ELECTRONS, THEY WOULD PERFORM BETTER AND DEVOUR LESS POWER

Alexander Hellemans

European researchers are now studying a new light-emitting alloy of silicon and germanium to obtain photonic chips, which can revolutionise computing.

Over the last 50 years photons, the particles that make up light, have replaced electrons to transfer data in communication networks. The very large bandwidth of optical signals has driven the enormous growth of telephone systems, television broadcasting and the internet.

However, photons have not yet replaced electrons in computers. Using light for transmitting data in processor chips and their interconnections would allow a substantial increase in the speed of computers (the speed of on-chip and chip-to-chip communication could be increased by a factor of 1000) and at the same time reduce the power required for them to operate.

Today's most advanced microprocessor chips can contain tens of billions of transistors, and their copper electrical interconnections produce large amounts of heat when in operation. Unlike photons, electrons have a mass and an electrical charge. When flowing through metals or semiconductor material, they are scattered by the silicon and metal atoms, causing them to vibrate and produce heat. Therefore, most of the power supplied to a microprocessor is wasted.

The challenge of emitting light from silicon

Today the whole electronics industry is geared up to use silicon in computer chips because of the advantageous electronic properties of this material and its availability. It is a good semiconductor, a very abundant element and – as silicon oxide – a constituent of glass and sand.

However, silicon is not very good at dealing with light because of its crystalline structure. For example, it cannot generate photons or control their flux for data processing. Researchers have investigated light-emitting materials, such as gallium arsenide and indium phosphine, but their application in computers remains limited because they don't integrate well with current silicon technology.

Shaping photonics chips: towards a revolution in the electronics industry

Recently, European researchers reported in the journal Nature an innovative alloy of silicon and germanium that is optically active. It is a first step, says Jos Haverkort, a physicist at the Eindhoven University of Technology in the Netherlands: "We showed that this material is very suitable for light emission, and that it is compatible with silicon."

The next step is to develop a silicon-compatible laser that will be integrated into the electronic circuitry and be the light source of the photonics chips. This is the ultimate aim of the project SiLAS, supported by the EU programme FET. The team, led by Erik Bakkers from the Eindhoven University, also includes researchers from the universities of Jena and Munich in Germany, Linz in Austria, Oxford in the UK and from IBM in Switzerland.

High temperatures needed for polymer production today are not suitable for crafting silk-based materials

To create the laser, the scientists combined silicon and germanium in a hexagonal structure, which is able to emit light, overcoming the all known uses of silicon where the atoms are arranged in a pattern of cubes. And it has not been easy. An initial attempt to coax silicon into adopting a hexagonal structure by depositing silicon atoms on a layer of hexagonal germanium failed.

Silicon stubbornly refuses to change its cubic structure when grown on planar hexagonal germanium, explains Jonathan Finley of the Technical University of Munich, and who took part in the research by measuring the optical properties of the created silicon samples. "You have to convince Mother Nature to allow the growth of this unusual form of silicon germanium. It likes to grow cubic, that is what it does," he says.

However, over the years the research group at Eindhoven (pictured on the front page) has developed expertise in growing nanotubes, and reasoned that what does not work on a planar surface of germanium might work on a curved surface of a nanotube. And this time things worked out. "What we did was to use a nanowire of gallium arsenide, which has a hexagonal structure. So we had a hexagonal stem, and we created a silicon shell around the core, which also had a hexagonal structure" (pictured above) says Haverkort.

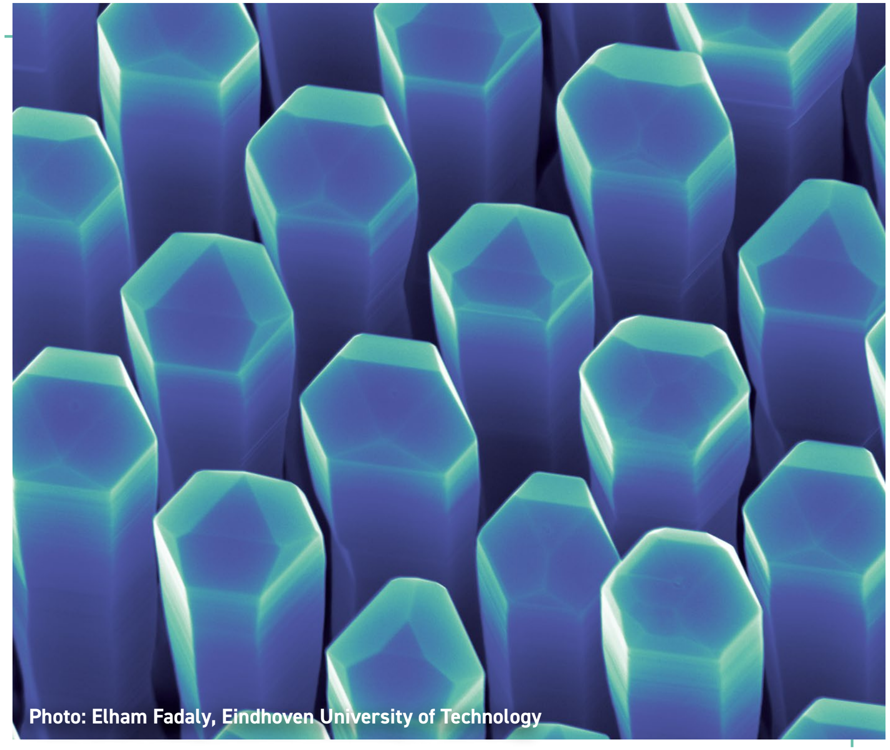


Photo: Elham Fadaly, Eindhoven University of Technology

By varying the amount of silicon and germanium deposited on the nanotubes, the researchers found that the hexagonal alloy was capable of emitting light when the concentration of germanium was above 65 percent.

Now, the proof of the pudding would be a demonstration of lasing, in other words how the silicon-germanium alloy can amplify and emit light as a laser, and measure it.

There are several open questions to resolve before silicon germanium can become fully integrated with silicon-based electronics, remarks Haverkort: "First, these devices have to be integrated with existing technologies and that is still a hurdle." He expects that future quantum computers will use applications such as low-cost silicon-based LEDs, optical fibre lasers, light sensors, and light-emitting quantum dots.

In general, the shift from electrical to optical communication will boost innovation in many sectors, from laser-based radars for autonomous driving to sensors for medical diagnosis or air pollution detection in real-time.

VIRTUAL COLLABORATION FOR IMMERSIVE EVENT CAPTURE

SMARTPHONE CROWD RECORDINGS AT PUBLIC EVENTS CAN BE COMBINED INTO 3D VIDEOS FOR EVENT RECONSTRUCTIONS

Recording events with smartphones to share them on social media is one of modern life's common practices. However, how many times do people actually watch the footage they have taken? Limited perspective and poor image quality can make for unsatisfying viewing, failing to accurately convey the feeling and atmosphere of the occasion. SceneNet aims to revolutionise this by making your own recorded videos into a virtual collaboration amongst all fellow event attendees, creating a 3D immersive experience.

The project, funded under the EU's FET programme, came about after project leader Dr Chen Sagiv, who holds a PhD in applied mathematics from Tel Aviv University, Israel, and her husband attended a Depeche Mode concert. They had noticed the hundreds of smartphone screen lights held by fans all attempting to capture the moment for posterity, hence the idea to crowdsource everyone's videos from the event was born.

The first obvious challenge involved in SceneNet's initial development stage was how to sift through and put together footage from thousands of different sources, recorded in countless formats and quality. To solve this challenge, the project developed a way to identify matches between images and videos and integrate them in the right place, just as in a puzzle.

According to Sagiv, footage can be enhanced to reduce background noise, motion blur and bad lighting, for example. Sounds simple, right? Sagiv explained in the Times of Israel how the system "stitches together the videos at their edges, matching the scenes uploaded by the crowdsourced devices." It's a very complex process because "you have to match the colours and compensate for the different lighting, the capabilities of devices and factors that cause one video of even the same scene to look very different."

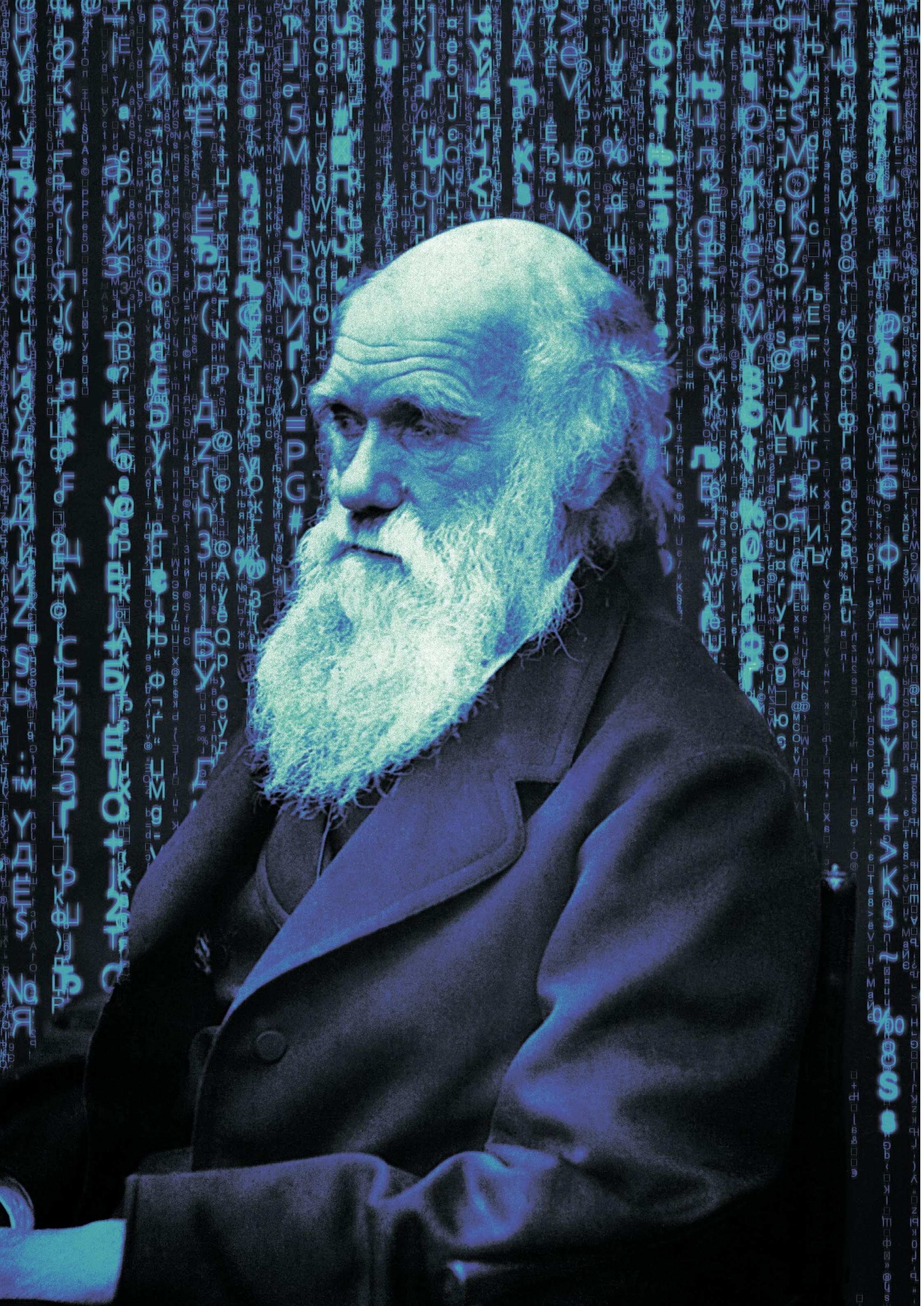
Today, the computing power required to support this technology is enormous and may currently limit real-time execution of 3D reconstruction, but in this era of constant innovation, processor performance will become less of an issue overtime. "SceneNet needs to leverage these technologies to parse through thousands of videos that will be uploaded to the cloud, searching each one for its common denominators and determining what must be done to a clip in order to make it look like a natural part of the final presentation," said Sagiv.

SceneNet could potentially redefine virtual reality and media, which are both likely to take on a whole new dimension through these types of immersive and interactive features, such as individuals being able to edit or view 3D videos and environments from any vantage point.

Computer science may soon provide the computational resources for crowdsourced video making

The implications of this technology extend far beyond your favourite singer's current world tour or sporting event. Real-life applications of 3D virtual environments based on mobile crowdsourced videos could be used in law enforcement, allowing witnesses to aggregate their smartphone images to reconstruct a crime scene. In defence strategies for comprehensive terrain mapping of remote areas. Surgeons could view complex medical operations from multiple angles in high definition 3D. In real-estate and construction, architects and builders could remotely monitor progress on the ground in 3D and display it to prospective property buyers. And in education and just for fun, students could collaborate in making 3D videos of their school projects.

If it realises its full potential, the numerous applications of SceneNet are really limited only by imagination.



PROGRAMMING THE FORCES OF EVOLUTION

ROBOTS CAN USE COMPUTATIONAL NATURAL SELECTION TO BOOST EXPERIMENTAL POWER AND AVOID HOURS OF TRIAL AND ERROR

Bradley van Paridon

The genius of evolution is rarely seen in action, so the invisible hand guiding the direction of biological systems is often taken for granted. However, by applying the principles of natural selection to research questions and designing robots to carry out these tasks, scientists are creating the world's first evolutionary machines.

It sounds like something from science fiction, but there are immediate practical benefits to this forward-looking approach. Designing everything from pharmaceuticals to cellphones requires countless hours of trial and error in a lab, experimenting with combinations of new materials, then laboriously testing and optimising them. Fortunately, help may be on the way in the form of a computational robotic system that applies the principles of evolution to the process of materials discovery.

"It's evolution first," says Dr Lee Cronin, a chemist at the University of Glasgow, UK. "Evolution created biology, not the other way around." It led to the astonishing complexity of the biological world and Cronin believes that it is the perfect solution for materials science too.

"We needed a process to generate physical entities, put them into an environment and see if they live or die," he explains. For this, Cronin and colleagues in the EU project EVOBLISS designed a modular robot that would mix oil droplets on a petri dish and move them around. The behavior of the droplet was recorded, along with the starting conditions that created it.

In this way, they could screen and select droplets with certain material characteristics: if they behaved in the desired way they 'lived' and the conditions to create it survived. If they didn't they 'died' and were discarded.

This type of evolutionary search greatly cuts down on time and costs because the robot performs thousands of trials without interruption. For Cronin though, the real advantage of the approach goes beyond screening. "Evolution does so much more, it generates novelty to solve problems you never thought possible,"

Evolution-powered computers are becoming a powerful tool to face complex biological problems such as antimicrobial resistance

he says. With the robot they can explore unexpectedness, meaning when a droplet behaves in a novel way, the conditions can be saved and further optimised.

The concept of using evolution-powered computers is proving incredibly effective for dealing with complex systems. Alfonso Jaramillo, Professor of Synthetic Biology at the University of Warwick, UK, developed a similar approach to solve complex biological problems like combatting antimicrobial resistance. In his evolutionary computer, real bacteria are altered to avoid being infected by bacteriophages. When a phage 'solves' the problem of beating the bacteria's defenses it survives. There are incalculable amounts of molecular interactions occurring during this process, but, according to Jaramillo, "when evolution takes place you already know the outcome of the reaction." The computation is done within the virus itself and the data stored in its genome.

Back in the materials lab the situation is the same. The computations are not being performed on a computer; they are done physically in the robot. Cronin says data stored on a silicon chip is only a representation of reality. "We are using our system to optimise reality."

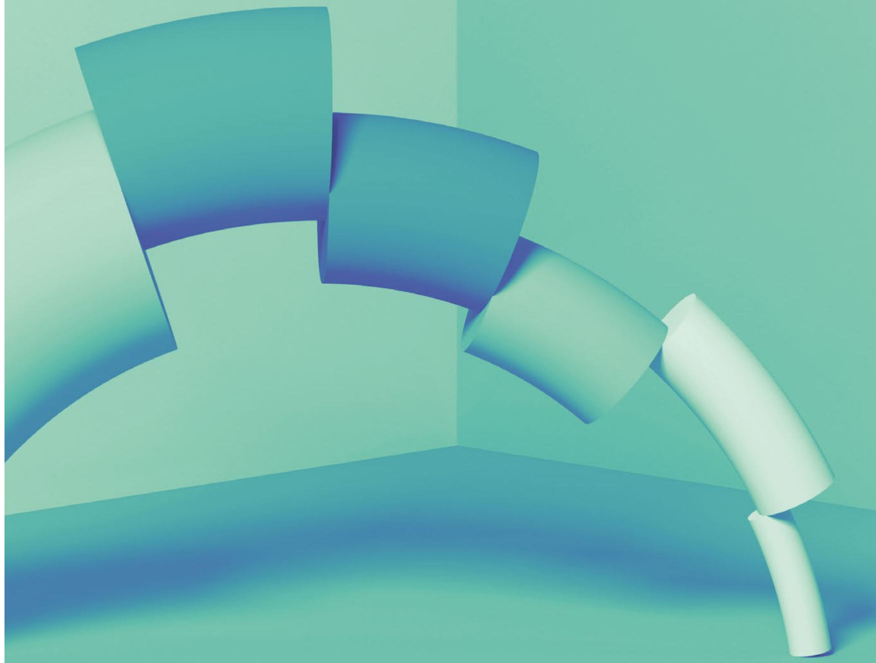
Blair Brettman, assistant professor at Georgia Tech School of Material Science and Engineering, US, previously worked in industry doing many of the experiments EVOBLISS now promises to automate. She is optimistic about the technology's ability to reduce human labour and explore how complex materials will behave. "Most commercial materials are mixtures of lots of different things and it's very difficult to predict how the combinations will react."

However, Brettman does see some challenges. "Most limiting is what you have to characterise or learn about the sample," she says. "If all you want to do is look at how well a liquid wets that will be relatively easy. But if you want to look at how a liquid penetrates a solid that's going to be much harder to analyse." The more complex the material is to manipulate and the variables to measure, the more difficult scale-up will be.

This is one reason why the researchers started with liquid materials but conceptually it can be extrapolated to any material. So far, platforms to specifically optimise three classes of materials have been designed: cleaning liquids, gold nano-clusters that detect chemical contaminants, and new drug-like organic molecules.

With this new appreciation of evolution as the starting point, and not the consequence of biology, evolutionary machines seem set to harness this unique force of nature. EVOBLISS is supported by the EU FET programme.

IMPACT ON CAREERS AND TECHNOLOGICAL TRENDS



FET HAS BEEN KNOWN TO TURN SCIENCE-FICTION INTO REALITY. DISCOVER THROUGH OUR STORIES ON HOW PAST AND ONGOING FET PROJECTS ARE OPENING UP NEW FIELDS WE NEVER THOUGHT WOULD EXIST IN OUR LIFETIME

NEXT-GEN DRUG TARGETING THANKS TO EVS

UTILISING A CELL'S OWN MOLECULAR DELIVERY SYSTEM COULD ENABLE SPECIFIC BIOMEDICAL TREATMENTS

In the world of drug delivery, getting an active compound to the right tissue or organ before the body's defences break it down can make the difference between wellbeing and sickness, life and death. Clever capsules and coatings can boost the drug effect but every molecule has a shelf life once it enters the body, and this severely hampers effectiveness and can lead to side effects.

Now researchers are looking to utilise a live organism's own cellular machinery to deliver medicines right where there are needed by using extracellular vesicles (EVs). EVs are cell-derived, membranous particles that mediate intercellular communication by transferring biomolecules such as proteins and RNAs. Scientists are increasingly looking at these EVs as a means to deliver drugs in the fields of nanomedicine, cosmetics and nutraceutics. EVs offer several advantages, if they can be utilised.

VES4US is a €3M European project funded by the FET programme that aims to develop a radically new platform to reduce the cost and the time for production and functionalisation of EVs. Using a sustainable biosource, the project aims to enable their exploitation as tailor-made products in the fields of nanomedicine, cosmetics and nutraceutics. This could allow the development of natural nanocarriers tailored for industry with unprecedented abilities for drug delivery in specific tissues such as brain, lung, skin, dendritic or tumour cells.

"In VES4US the scientific approach is focused on market and social needs. Basic science and industrial worlds will work together to reach fruitful results in breakthrough emerging technologies and knowledge for the biotechnology, nanotechnology and bioscience sectors," says Antonella Bongiovanni, VES4US coordinator and researcher.

The discovery of EVs as natural carriers of functional small molecules and proteins has raised great interest in the drug delivery field. But systemically delivered EVs accumulate in liver, kidney and spleen, and some mammalian derived secreted EVs have shown limited pharmaceutical acceptability because of their source. To work around these issues, VES4US will start by selecting a source of EVs that will ensure the purity and quality needed to act as effective natural nanocarriers. There are currently few raw materials to make this happen and the technology to extract EVs is far from perfect for industrial scale, resulting in poor quality EVs with high costs.

"VES4US aims to overcome present limitations by developing a biocompatible and cost-effective nano extracellular vesicle-based drug delivery system, which would enhance bioavailability and improve the efficacy and safety of loaded bioactive compounds," explains Antonella.

VES4US results could replace less acceptable tumour or animal-derived pharmaceuticals or chemical liposomes, as future vehicles for targeted drug delivery, influencing health and human wellbeing. The biotech industry generates millions of euros of revenue and sustains a sizeable work force, and the global market in exosomes (a type of EV) was around $3M in 2016 and the forecast is $2.28Bn in 2030, according to a Grand View Research report.

This project was launched on September 2018 and will last until August 2021. The project is coordinated by the National Research Council of Italy (Italy) and partners are the Institute of Technology Sligo (Ireland), the Swiss Federal Institute of Technology (Switzerland), University of Ljubljana (Slovenia), Max Planck Institute for Polymer Research (Germany) and ZABALA Innovation Consulting (Spain).

Together with other EV-based FET projects, INDEX, evFOUNDRY, GLADIATOR, and MINDGAP, they formed a cluster and created an evMANIFESTO which provides roadmap for EV-based research.

EXPLORING THE UNEXPECTED. A CHAT WITH PAOLO DARIO

THE WORLD-RENOWNED PIONEER OF BIOROBOTICS TELLS US: "THERE ARE 40 YEARS OF RESEARCH BEHIND THE BIONIC HANDS WE HAVE BUILT!"

Loredana Pianta

From the bionic hand to a Fantastic Voyage-inspired capsule in the human body: Paolo Dario, founder of The BioRobotics Institute of the Sant'Anna School of Advanced Studies, shares the most important achievements over the last 20 years in their revolutionary integration of robotics with biology and medicine.

Many of the prototypes that have made the history of biorobotics worldwide are visible in a showcase set up at The BioRobotics Institute of the Sant'Anna School of Advanced Studies in Pontedera, near Pisa, Italy. Among these are the bionic hands, which in recent years, have given new hope to amputees. Not only can they now return to grab objects but also feel them with a restored sense of touch.

In front of the display we met Professor Paolo Dario, founder of the Institute. He has trained, over the past few decades, generations of researchers who are changing our lives with their studies.

He explains: "A first research focus is on bioinspiration and biorobots. We studied worms, eels, lampreys, octopuses. As if we were modern Leonardo da Vincis, we analysed how many organisms work. We didn't copy them but drew inspiration to create new engineering principles, new design principles, mechanisms and materials."

"A second focus area is artificial hands and prostheses. This is also part of what was a long-standing dream: to create hands capable of both dexterity and sensitivity. I would specifically mention the CyberHand project. The third focus area is a very fundamental project to me, Neurobotics. No one had ever thought about systematic collaboration with non-engineering sectors before, for example with neuroscience."

"I would just mention one of our ideas: a piloted capsule able to explore inside the human body, almost as it was in Fantastic Voyage, the book and the film in which a submarine is reduced to very small dimensions. Then how would it be controlled with the brain? What kind of interface could be used? Or perhaps you may remember Doctor Octopus in Spider-Man, that mad scientist who has a kind of octopus on his shoulders, inserted into his nervous system. Well, can the brain control a body other than its own?"

Professor Dario underlines the fact that all these achievements would not have been possible without the support of the EU programme FET: "It meant embracing new horizons while setting practical goals in the end, and understanding that applications will be a long way off still. There's 40 years of research behind the bionic hands we have built!"

"So exploring the unexpected. And this is one of the problems facing Europe. Many times I have asked myself this: if a 23- or 24-year-old boy like Zuckerberg had come to talk to one of the many top European banks or venture capitalists, they would not have given him a euro! The real challenge for Europe is to leave the way open to those who are disruptive thinkers, to the movers and shakers. And the FET programme was all about this."

LEVITATION BECOMES A REALITY

ONE DAY WE MAY NOT ONLY SEE, HEAR AND TOUCH DEVICES, BUT ALSO FEEL THE OBJECTS SHOWN ON THEM AT THE TIP OF OUR FINGERS. THANKS TO LEVITATION, 3D ITEMS WILL BE CREATED USING FLOATING PIXELS

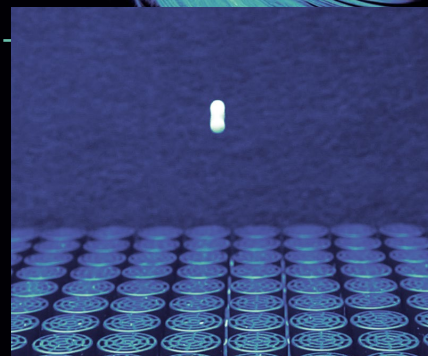
Levitation is an old dream of humankind. For centuries, magicians gave audiences the illusion of defying gravity, seemingly making objects of people float into the air. Now European scientists are turning this into reality.

Researchers at the University of Glasgow, UK, have managed to suspend little polystyrene particles in mid-air, supported only by ultrasonic acoustic waves. This is levitation. The technology may lead to new kinds of displays to command machines and hence revolutionise human-machine interactions. Data, for example, will not appear anymore on a flat screen, but become physical levitating objects, rising before us in mid-air; and, with simple, intuitive gestures, people could work on them.

"If I was working on a model of a car, instead of having it of clay, I could have that model created in front of me, with multiple little pixels in space, marking out the surface of the car. For example, I could make gestures to change the way the headlights work," explains Stephen Brewster, Professor of Human-Computer Interactions at the University of Glasgow.

Or take a music player with a levitating play button. The user would only need to tap a finger in the air to turn the music on or off.

The study runs under the EU project Levitate, supported by the European FET programme. @



A PORTABLE DEVICE TO TREAT MAJOR BRAIN DISORDERS REMOTELY

SPANISH INNOVATOR ANA MAIQUES HAS DEVELOPED A WIRELESS DEVICE TO TREAT BRAIN DISEASES AT PATIENTS' HOMES. HER RESEARCH HAS HAD A CONSIDERABLE BOOST DURING THE COVID-19 EMERGENCY

Claudio Rocco and Marta Calderaro

Ana Maiques has always been attracted by the mysteries of the human brain: "To unlock it is like a crusade of humankind." Twenty years ago she decided to use her economic professional background in the neuroscience field.

Nominated by IESE as one of the most influential entrepreneurs under 40 in Spain, winner of the 2014 EU Prize for Women Innovators – to mention some of the awards achieved – she has proved that high-risk research can become a business model.

In 2000 Maiques founded the Barcelona-based company Starlab, together with the physicist and mathematician Giulio Ruffini, to study computer-controlled brain stimulation. "The objective of the company was to do brain science and then take it to the market. Giulio is a pure scientist and I am a business person. This helped to create both cultures in the company."

The following step was the creation of the US and Spain-based spin-off Neuroelectrics that has developed wireless telemedicine platforms and medical devices for brain monitoring and stimulation. They

designed a head cap with 32 electrodes, capable of treating many neurological disorders such as epilepsy, Parkinson's, Alzheimer, anxiety and depression.

Maiques explains: "The electrodes can pick up brain signals. As neurons communicate electrically, we can make an electroencephalogram (EEG). Moreover, the electrodes can inject current into the brain. So the technology has the potential to both make a diagnosis and provide therapy through electrical brain stimulation. Another advantage is the absence of major side effects, compared to drugs. For example, in pathologies like epilepsy it is a very big issue."

Telemedicine has been crucial during the coronavirus emergency and the restrictions to avoid the spread of the infection. Maiques says: "When the Covid-19 pandemic broke out, patients couldn't go to hospitals to receive depression treatment."

Telemedicine has been crucial during the Covid emergency and the restrictions to avoid the spread of the infection

Such long-term research involves high-risk investment. This is why public support of the EU Future and Emerging Technologies (FET) programme has been essential to help Maiques' activity and career to take off."The FET support for our projects HIVE and LUMINOUS has been really important. Without it, the results described above wouldn't exist. In 2006 we had only developed the technology to read the brain. When we had the opportunity to submit a project for FET, we started to think big: what is the potential to interact with the brain? If you can read the brain, can you write on it? And the EU programme allowed us to put together a really long-term visionary proposal: can two brains communicate?"

Today Ana Maiques is one of the experts of the advisory board of the EIC pilot, who recently published its EIC Vision document. The EIC aims to offer an advanced science-and-technology research programme and an accelerator for start-ups and SMEs. It will therefore integrate FET, now EIC Pathfinder, and the SME Instrument, now EIC Accelerator.

She says: "What the EIC wants to do is to transform hi-tech science into successful business. For the first time it has created a blended finance mechanism, allowing the European Commission to provide both grants and direct investments to companies."

"The generation of companies we want to support in Europe should address deep-tech solving problems. If you want this, you need relevant investment, high-risk research and preparation to failures. That was the FET spirit and we are so happy that the Pathfinder is included in the EIC: it will give founders the visibility of their deep-tech companies and potential companies which emerged based on European funding. The EIC should create a lighthouse where all the entrepreneurs in Europe can look at."

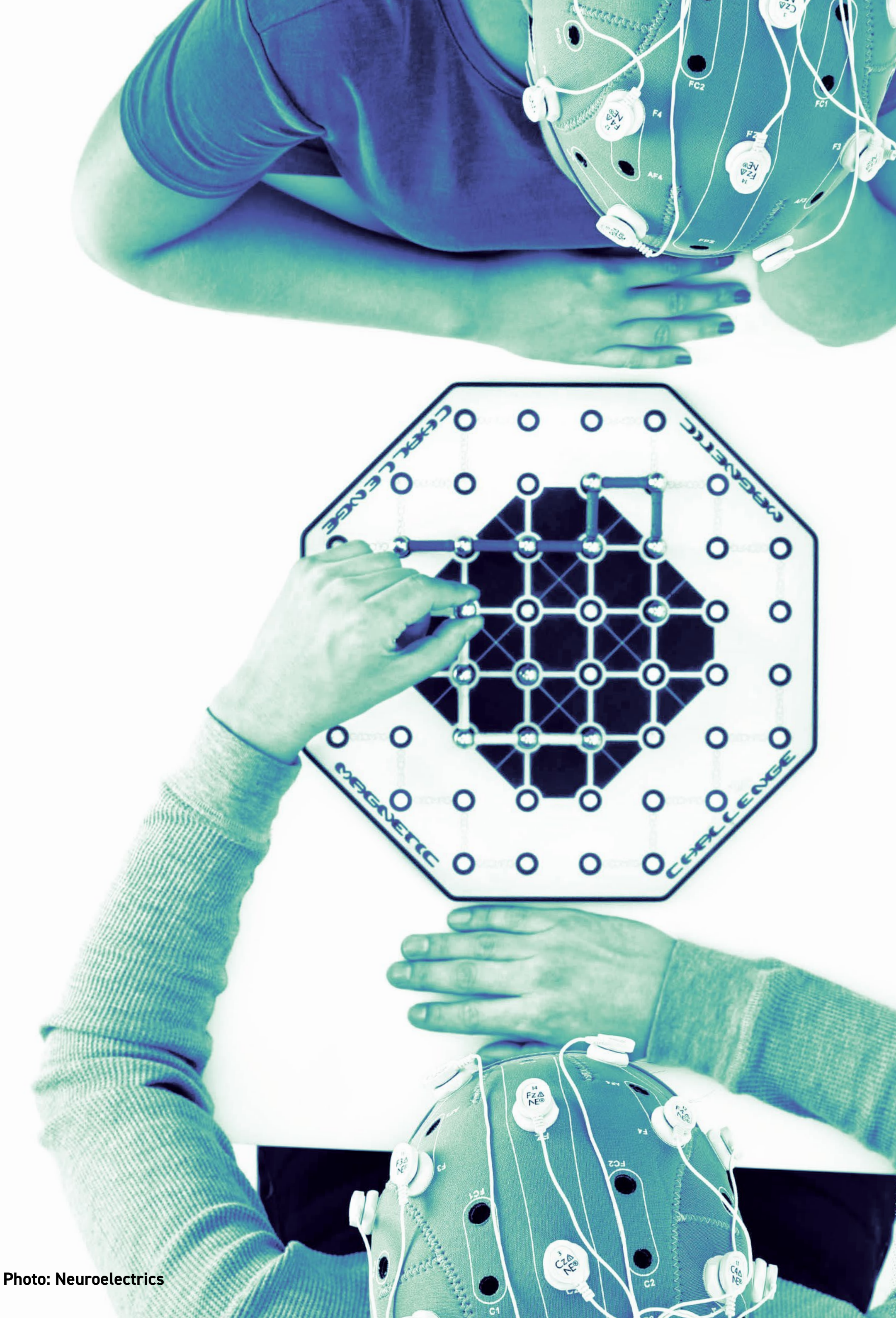


Photo: Neuroelectrics

The emergence of a science-driven breakthrough innovation is the essence of the FET programme, pioneering programme at the basis of the EIC and its Pathfinder for Advanced Research. Stimulating effects of FET through communication and outreach is the main aim of the FETFX project.

The FETFX project acts as an information hub, capable to support all FET projects in their communication and outreach activities and to increase their influence and impact among society, policy makers and research and innovation communities.

The project turns up the volume for opinion leaders and multipliers, general public and the wider business community, who may investigate, benefit, invest or just promote the emerging technology supported under the EIC Pathfinder Pilot and the related FET programme.

Acting as a communications hub across various media, FETFX stimulates the debate on the most inspiring stories about science-to-technology breakthroughs, through the collection of relevant European resources and inspiring funded projects.

Join FETFX and discover FET, currently supported by the EIC, learn about their impact on our lives and meet the great minds turning the future into reality.

WANT TO SHAPE THE FUTURE WITH US?

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FETFX: VOICES FROM THE FUTURE

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