

Impact from excellence



2018

Annual report





Tyndall National Institute

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Dr Niamh Creedon and Aidan Murphy, PhD student from Microelectronic Circuits Centre Ireland (MCCI), using their app-controlled ADuCM350 evaluation board with an integrated nanowire sensor to detect bovine diseases.

Chairman's message

Tyndall National Institute is a unique partnership between University College Cork (UCC) and the Department of Business, Enterprise and Innovation. This partnership allows our team of 500 world-class researchers, postgraduate students and support staff to deliver excellent research which has a significant impact on society and the economy and is helping position Ireland as an international innovation leader.

The past year has been an exciting one for Tyndall as we embarked on developing a new strategic plan. Our ambitious plan will build on the success of the past five years and involve a major expansion of our research activities and infrastructure under the Government's National Development Plan 2018-2027 (NDP). The NDP investment ambition is to see Tyndall double in size over the next decade and expand our role as a leading global research institute.

In these uncertain times, we need to ensure that Ireland continues to attract inward investment while improving the value-add and export performance of our small and medium-sized enterprises (SMEs). To minimise our vulnerability to external shocks, we must increase the contribution from the indigenous sector of the economy while enhancing the resilience and sustainability of the foreign direct investment (FDI) sector. As our tax regime becomes less of a differentiator, talent and the innovation ecosystem become more significant in creating and growing the economy.

At Tyndall, we play a key role in providing the talent and scientific and technological innovation that is required to move Ireland's status from innovation follower to innovation leader. Our research ranges from atoms, through systems, to applications. Achieving excellence in this research is the foundation for our success and is the basis for our impact and innovation. The Research Highlights section of this report includes examples from our key publications in 2018 and gives an indication of our strength across the full spectrum of fundamental through applied research.

Supporting Irish companies as they compete on the basis of knowledge and technology is a priority for all of us at Tyndall. We support these companies through knowledge transfer, through access to our technology infrastructure and most importantly through the movement of our graduates and researchers into industry.

Tyndall's success is due to the quality of our people. Attracting, retaining and developing the best is a huge priority as we seek to scale up to become a leading global research institute.

We offer an attractive environment that values multidisciplinary research and provides access to world class infrastructure.

At Tyndall, our postgraduate education programme is a very important contributor to our success. Tyndall has a long history in postgraduate education; we've been hosting postgraduate students since 1981. At the end of 2018, there were 112 PhD and 27 master's candidates pursuing their degrees at Tyndall.

A significant development during the year was the new partnership between

Science Foundation Ireland (SFI) and Engineering and Physical Sciences Research Council (EPSRC), part of UK Research and Innovation, to invest €39 million in seven new joint Centres for Doctoral Training (CDTs). The Irish Photonic Integration Centre (IPIC) at Tyndall will collaborate with Queen's University Belfast and the University of Glasgow on one of these CDTs, which will enable doctoral students based in Irish institutions to benefit from training opportunities and collaboration with higher education institutions in the United Kingdom (UK).

This will further enhance our ability to provide the talent required to assist Ireland in meeting the challenge of continuing to attract FDI and improve the performance of Irish-owned industry on the global market.

We greatly appreciate the support of UCC President, Prof. Patrick O'Shea, and his management team as well as the critical support and guidance received from the Department of Business, Enterprise and Innovation during the year.

I would like to acknowledge the retirement of Prof. Willy Sansen from our board during 2018, and I would like to thank him for his contribution to Tyndall over the past six years. I would also like to welcome Sean O'Sullivan to the board.

On behalf of the board and all at Tyndall I wish to thank Prof. Eoin O'Reilly, our chief scientist, for his sterling work as interim CEO, which contributed to making 2018 such an outstanding year for us. On the same note, I would like to take this opportunity to welcome our new CEO Prof. William Scanlon, who joined us in September 2018 from Queen's University Belfast, and look forward to working with him as we embark on our new strategic plan.

We stand at the threshold of a bright and exciting future. Thanks to our world-class research teams, Tyndall is already a global leader in a number of key technologies and taking a leadership position in a number of other innovation areas. Our ambitions for the future have been matched by the vote of confidence received from Government by including Tyndall's development as a key objective of the NDP. We aim to repay that confidence in the years ahead.



Eoin O'Driscoll
Chairman

*Prof. William Scanlon,
Tyndall CEO (left), and Eoin O'Driscoll,
Tyndall chairman.*



CEO's message

This is my first annual report since joining Tyndall National Institute as chief executive officer. I am looking forward to developing our new strategic plan 'Tyndall 2025', which has an exciting ambition to substantially expand our research activities and capabilities and will result in a doubling in scale for the institute over the coming years. The new strategy has had input from a wide range of stakeholders, internally and externally, and will guide us towards global leadership in Deep Tech.

Deep Tech is widely accepted as being technology that is based on tangible engineering innovation or scientific advances and discoveries and often associated with applications that relate to societal challenges.

Tyndall has a significant pedigree and established reputation in key enabling technologies for Deep Tech, including

advanced materials, semiconductors, quantum technologies, nano and microelectronics, photonics and photonics integration. These underpin our rapidly expanding portfolio and ambition in fields such as micro – and macro-energy, bioelectronics, biophotonics, high performance communications, the internet of things (IoT), smart sensors, hardware security, blockchain, robotics and automation, Industry 4.0, augmented reality (AR) / virtual reality (VR), novel computing architectures and AI at the edge.

Our leadership position in these areas will enable us to make a real contribution to addressing some of the key challenges facing humanity, including climate change, sustainable living, water and food supply, cybersecurity, energy, and the provision of healthcare to an expanding and ageing population.

It will also enable us to continue to attract the key industrial partners and world-leading researchers which are critical to our international competitiveness and our ability to make a real and lasting contribution to the Irish economy.

Looking back over the past year, 2018 was another phenomenally successful year for Tyndall, which saw us build on our position as a leading centre of scale in translational research while continuing to further the development of information and communications technology (ICT) – innovation in Ireland.

While it is not possible to cover all of the amazing work within the Institute, I would like to give you a flavour of the outstanding achievements which have become the hallmark of Tyndall.

Everything we do at Tyndall is underpinned by the excellence of our research and the quality of our people. Our principal investigators, researchers, and PhD and master's students produce world-leading research that makes a direct and valuable contribution to society and to the Irish economy. At the core of our mission is the transfer to industry of new ideas, know-how and talent.

Our world-leading researchers produced 270 publications during the year, half of them in journals ranked in the top 20% in the world for impact. These journals included *Nature*

UCC President, Prof. Patrick O'Shea with Gediminas Juska, researcher at Tyndall who won Early-Stage Researcher of the Year at the UCC Staff Recognition Awards 2018.



Photonics; Nature Communications; Nano Energy; Nano Letters; Advanced Functional Materials; ACS Nano; and Physical Review Letters.

It was another record year for Tyndall research and innovation with licences, options and assignments executed and invention disclosures. The excellence of our staff was recognised through a number of awards during the year. Prof. Peter O'Brien received the Science Foundation Ireland (SFI) Best International Engagement Award and Dr Ivan O'Connell received the SFI Industry Partnership Award. In addition, three of our researchers received SFI Career Development and Starting Investigator funding and four received UCC staff awards.

2018 was a fantastic year for our researchers who are active in Europe and ably supported by our European (EU) Programmes Office. Of the 51 applications submitted for Horizon 2020 16 were approved for funding, a 31% success rate that is truly exceptional. Participation by Irish-based industry was very strong and for 50% of the companies partnering with Tyndall, it was their first time to be

involved in an EU project. Overall, in excess of €9 million was secured from EU programmes during the year, a significant increase on that achieved in 2017.

During 2018 we placed increased emphasis on start-up company activity, and this resulted in the establishment of Rockley Photonics Ireland. Several new startups are in the pipeline, with two of those expected to be established during the first half of 2019.

Funding from industry for the year was over €8 million. We also took a conscious decision to increase our engagement with the SME community and I am very pleased to report that one-third of all of our deals with industry partners during 2018 were with SMEs.

We also renewed our long-term relationships with a number of key clients, including Analog Devices, which you can read more about on page 26.

In another important development, we secured €8 million of support under the Government's Disruptive Technologies Innovation Fund (DTIF) to lead three key industry projects and to be a leading partner in a fourth. Tyndall teams, in

collaboration with industry partners, will be driving disruptive innovation on the key areas of connected health, smart wearables, blockchain-based energy trading and photonics manufacturing.

Also during 2018, Science Foundation Ireland, following an international review, agreed to fund significant growth for the Tyndall-based Irish Photonics Integration Centre (IPIC).

I wish to acknowledge the immense contribution of my predecessor, interim Chief Executive Eoin O'Reilly, and the tremendous support I have received from our chairman Eoin O'Driscoll and all of the members of the board since joining Tyndall in September 2018.

Finally, I must pay tribute to our staff and students whose dedication and commitment to excellence have been responsible for Tyndall's many achievements during 2018.



Prof. William Scanlon
CEO

Prof. William Scanlon, Tyndall CEO.



Scorecard

Global reach

Organised the Institute of Electrical and Electronics Engineers Nano 2018 event, the inaugural EnerHarv and All Hazards Forensic Conferences and PwrSoC in Singapore.



Photonics Ireland exhibited at Photonics West alongside **IDA Ireland, Enterprise Ireland (EI)** and Irish companies



ASCENT, the EU infrastructure access programme (with IMEC and LETI) led to 87 projects involving researchers from 22 countries



Keynote speeches in Korea, Italy, Finland; many invited talks; EPSRC CDT Panel Chair; Academy of Finland Funding Panel; European Research Council review panels; Photonics Europe Si-Photonics Co-Chair (France)

Research excellence

Stefan Andersson-Engels
elected as SPIE fellow

EPSRC/SFI Centre for Doctoral Training

270
papers published



Three SFI Career Development Awards and a Starting Investigator Award

6

IPIC SFI Research Centre approved for second term of six years

10 patents filed
30 inventions disclosures

People

Two SFI Science Awards and four UCC staff awards

80%

response rate to the inaugural Tyndall People Survey

Year-end headcount @ 447 (2017: 437)

Initiated our Athena SWAN Bronze application due **Nov 2020**



112 PhD students
27 Master's students
16 PhDs completed

Industry engagement

€8m

In industry
programme
funding

**Magnetics team won
the UCC Invention
of the Year Award**



€0.5m of
licensing income

One start-up spin-in,
Rockley Photonics Ireland

10 commercial
licences/options/
assignments

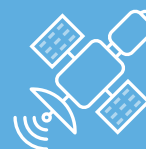
Infrastructure access

**Over
700**

users spanning
>150 projects

**200 access days
through infrastructure
access programmes**

ISO 17025
certification
achieved for
Space Component
Analysis Service



Funding



Excellent funding year with **42
proposals funded** to a value of **€65m**

**IPIC 2 €62m budget over
6 years (€26m from SFI)**

€16m

SFI Research
Infrastructure Award



Four successful DTIF projects
worth **€8m**, **three** as coordinator



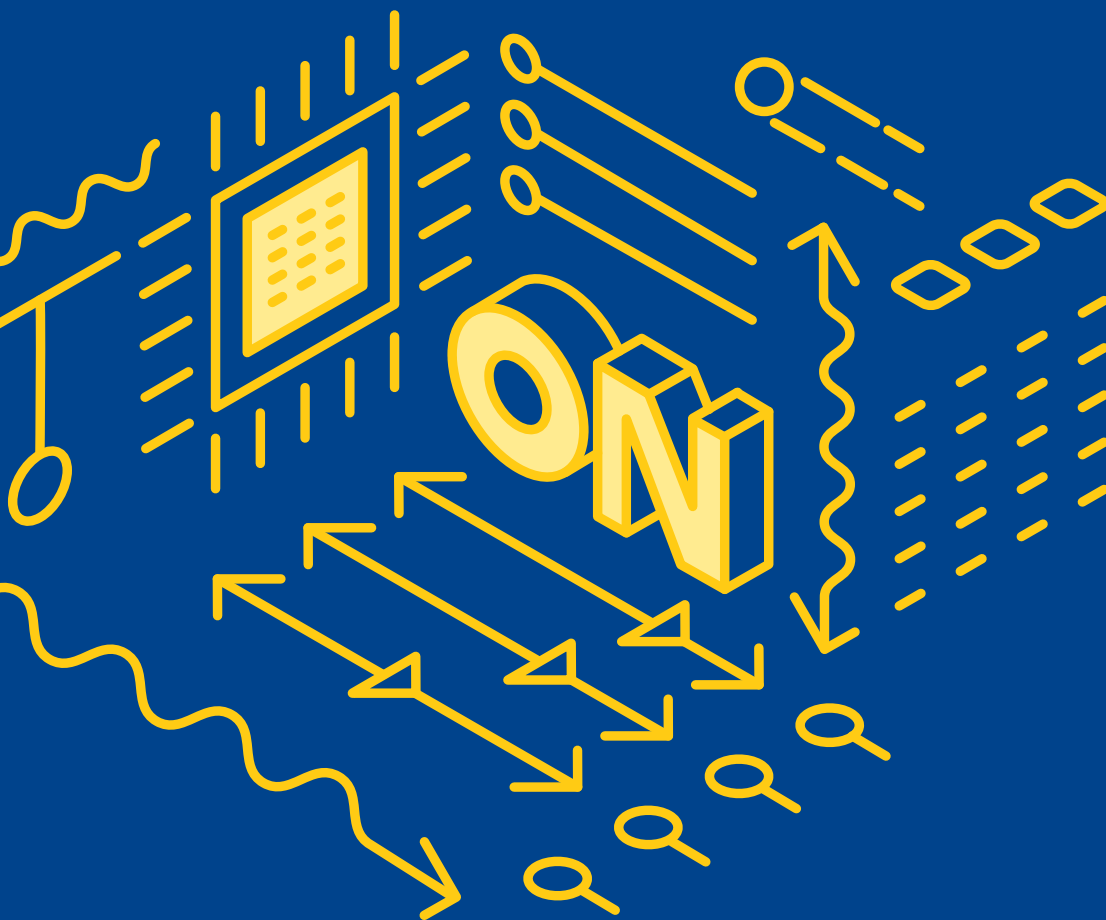
**Substantial Horizon 2020
wins @ 17 for 2018**
(~€10m, 33% success rate)

EPSRC/SFI CDT

(€5m, 25 PhD
students, 5 years)

Impact highlights

ON SEMICONDUCTOR
ACQUIRED TYNDALL
SPIN-OUT **SENSL
TECHNOLOGIES**



ON Semiconductor acquired Tyndall spin-out SensL Technologies

SensL Technologies Ltd, initially founded as a spin-out company based on Tyndall research, was acquired by the Nasdaq-listed Fortune 500 company ON Semiconductor.

In 2004, Tyndall researchers Dr Carl Jackson, Dr Alan Mathewson and business entrepreneur Joe O'Keeffe created SensL, based on Carl's PhD studies in photon detection systems. SensL's technology enables advances in industrial robotics, machine vision, drones, mobile and consumer applications. Working with ON Semiconductor opens up opportunities in the automotive, medical, industrial and consumer markets.

The acquisition saw SensL's silicon photomultiplier sensors, single photon avalanche diode arrays and LiDAR technology join forces with ON Semiconductor's sensing solutions, including autonomous driving and advanced driver-assistance systems applications. As part of ON Semiconductor, SensL is planning to grow its team based in Cork.

Carl also received the 2018 Tyndall Alumni of the Year Award, recognising the significant contribution he has made to the development of Single Photon Avalanche Diode (SPAD) sensors for low-light sensing applications and for his commercial successes with SensL Technologies Ltd.

The automotive sensor fusion demand is growing at an accelerated pace with a need for additional sensor technologies that are provided by the SensL team. Expanding our sensor technology assets and design capacity in Ireland will allow us to extend our leadership in established segments and to deliver new, world-class solutions for emerging segments.

Taner Ozelik

Senior Vice President and General Manager, Image Sensor Group, ON Semiconductor

L to R: Dr Carl Jackson and Joe O'Keeffe with Tyndall's entrepreneur-in-residence, Declan O'Mahoney.



Ireland's first smart wearables value chain

To enable Ireland to play a leading role in the emerging wearable healthcare space, the HOLISTICS project team, led by Dr Brendan O'Flynn at Tyndall, have created an industry-led value chain to deliver innovative smart wearable technologies for healthcare monitoring, as well as product prototypes for SMEs and multinationals. This has the potential to move global healthcare towards community-based, personalised medicine with smart connected medical devices operating remotely from the hospital setting.

Funded by the Department of Business, Enterprise and Innovation under the Disruptive Technology Innovation Fund, the €10m HOLISTICS project accelerates the creation and commercialisation of human-centric wearables for the next generation of personalised healthcare, specifically in the areas of respiration monitoring, cardiovascular monitoring, infection control and sports rehabilitation.

The ecosystem connects Irish-based companies with leading researchers to exploit state-of-the-art materials, ICT hardware, software, data analytics and visualisation technologies to develop a human-centric digital infrastructure to enable new paradigms of end-to-end solutions in the healthcare system.

HOLISTICS has the potential to drive significant changes in medical treatment by enabling diagnostics using wearable devices which give personal-health data. We see the Irish-based ecosystem of SMEs and MNCs aiding the transition of global healthcare towards personalised medicine. The enabling technology will facilitate remote patient care reducing pressure on health services due to a globally aging population.

Marisa Phelan,
Rapid Systems Platform,
Henkel Ireland



Dr Brendan O'Flynn, head of Wireless Sensor Networks, Tyndall, demonstrating wearable knee rehabilitation device developed at Tyndall.



Rockley Photonics established Irish R&D centre at Tyndall

Rockley Photonics, in collaboration with IPIC, established Rockley Photonics Ireland at Tyndall, to support their growing global activities in silicon photonics.

The collaboration represents a joint investment of €3.4m by Rockley and Science Foundation Ireland. The company has already hired four highly skilled employees and plan to grow their activities over the coming years.

The extraordinary growth in internet traffic combined with the non-stop demand for cloud-based services,

require integrated optical technologies that enable data centres to operate faster, more economically and at greater scalability. Transport rates are increasing to one-hundred gigabit per second (100GB), and this is expected to jump to 400GB in the near future – creating a major increase in energy usage as well as scalability issues unless new technologies, such as silicon photonics, are developed and deployed.

This investment strongly positions both IPIC and Rockley to take competitive advantage in the datacomms market, which is expected to reach \$6 billion by 2023.

This investment with IPIC will enable us to combine our expertise and utilise Tyndall's state-of-the-art facilities to develop groundbreaking early-stage technologies, which will have a huge impact on the future architecture design of large data centres.

Andrew Rickman,
Founder, CEO and Chairman
of Rockley Photonics

L to R: Prof. Eoin O'Reilly, chief scientist, Tyndall; Dr Sunit Rikhi, non-executive director and executive consultant for Rockley Photonics; Prof. Mark Ferguson, director general of Science Foundation Ireland and chief scientific adviser to the Government of Ireland; An Taoiseach Leo Varadkar TD, and Dr Patrick Morrissey, IPIC manager.



Disruptive solution for the treatment of atrial fibrillation

Atrial fibrillation is the most common heart rhythm disturbance in the United States (US) and Europe and can substantially increase a patient's risk of stroke, heart failure or loss of life. With more than one million hospital admissions in Europe each year, the cost to the healthcare system is over €40 bn.

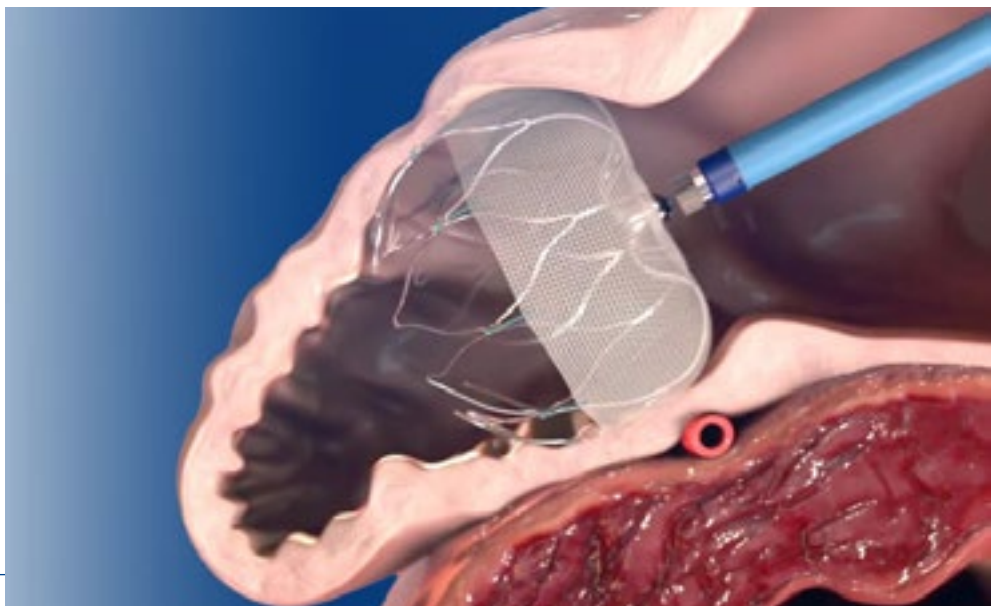
Treatment currently involves ablation (scarring of the tissue that allows incorrect electrical signals), however it is a difficult procedure with one year success rates as low as 28%. A >€9m investment by the Department of Business, Enterprise and Innovation (under the Disruptive Technology Innovation Fund) and AuriGen Medical, will create a partnership between Tyndall, AuriGen and TMD Lab, to address longstanding atrial fibrillation using an implantable cardiac device, incorporating a unique bio-photonic sensor and non-thermal ablation electrode.

This device will represent a truly disruptive solution, using dual wavelength laser ablation, in-situ verification of the ablation quality using image sensors, and image-guided navigation for device placement. The device will improve workflow efficiency, reduce procedure time and improve the overall quality of life for the patient.

AuriGen Medical, TMD Lab and Tyndall have unique experience, expertise and proprietary technologies, which place us in an unprecedented position to deliver a uniquely effective therapy capable of addressing both the stroke and arrhythmia risk associated with atrial fibrillation. Through this consortium, we can both improve R&D productivity while reducing the costs of translating these discoveries into new medical technologies to develop a revolutionary solution to address the needs of millions of patients.

Dr John Thompson MD,
CEO, AuriGen Medical.

*Basic mechanical LAA closure device.
Image: Courtesy of Boston Scientific.*



ESA Space Solutions Centre Ireland growing Irish business

The European Space Agency (ESA) Space Solutions Centre Ireland (SSCI), coordinated by Tyndall, enables technology and data originally developed for space applications to be used to generate viable commercial solutions in a non-space environment.

In 2018, eight start-ups joined ESA Business Incubation Centre (BIC), one of the three key functions of the ESA Space Solutions Centre Ireland. These exciting businesses all utilise space technology and data for applications here on Earth and range from intelligent implants for health applications and vehicle security to monitoring the health of bees. Since joining ESA BIC, these start-ups have raised millions of euro in equity funding.

In addition, four technology transfer demonstrator projects were funded to

enable established companies to access a new market using space technology. One such company, Skytek, has entered two new markets segments: marine insurance and international bulk tanker shipping. The company expects these products to generate annual multimillion revenues.

Led by Tyndall, the Centre is jointly funded by ESA and Enterprise Ireland with partners in the SFI-funded MaREI Centre for Marine and Renewable Energy Ireland, Maynooth University and Athlone Institute of Technology.

We worked with David and the ESA Space Solutions Centre Ireland (ESA SSCI) team to help identify exciting opportunities to adapt our existing space products for the marine industry. This has allowed Skytek to successfully commercialise within this sector. The ESA SSCI made crucial introductions, offered advice and access to key global shipping customers.

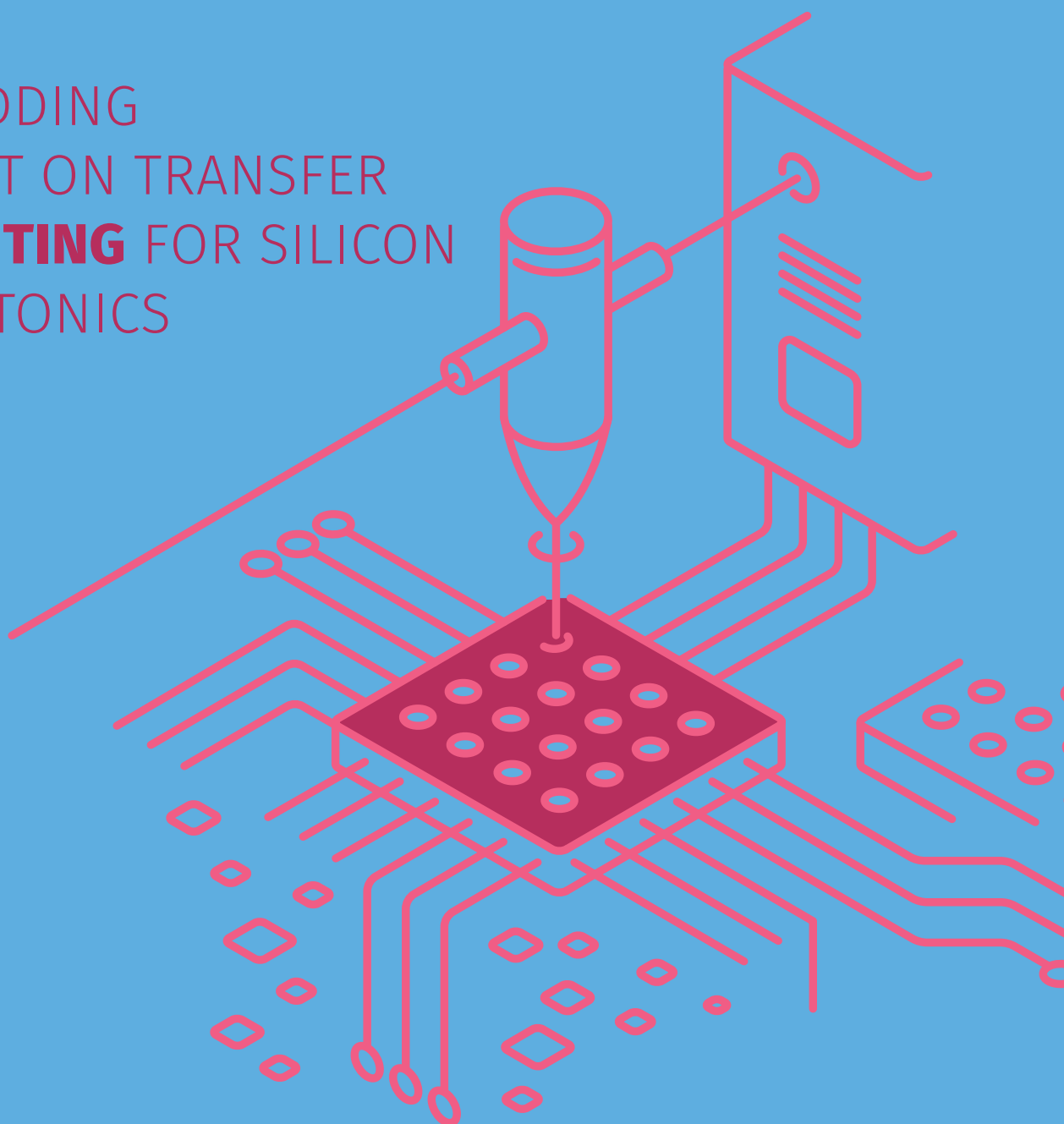
Sarah Bourke,
Chief Executive and
Co-founder, Skytek

Dr. Sarah Burke, CEO Skytek, David Gibbons, manager, ESA Space Solutions Ireland, Paul Kirwin, CTO Skytek and Karl Chadwick, senior programmer, Skytek at the deployment of the paperless vessels demonstration on board the Ardmare Cheyenne at the Port of Venice.



Research highlights

SHEDDING
LIGHT ON TRANSFER
PRINTING FOR SILICON
PHOTONICS



Beyond Moore's Law – 3D integration of 2D materials

As dimensional scaling of silicon devices approaches its limits, there is growing interest in exploring the integration of new functionalities, including novel memory, sensor or photonic elements, into the back-end-of-line (BEOL) of existing silicon complementary metal-oxide-silicon (CMOS) technology.

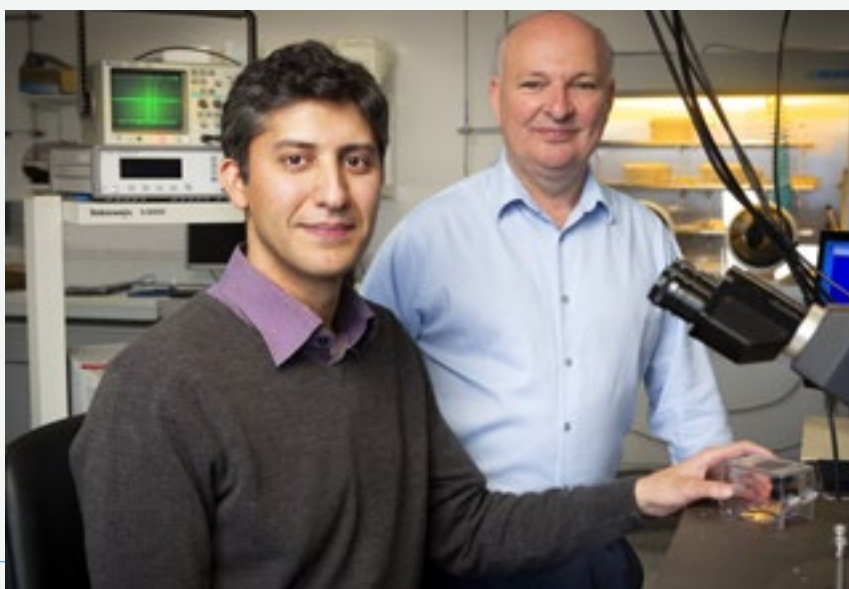
In this collaborative study between AMO, Universität der Bundeswehr München, Trinity College Dublin and Tyndall¹, we explored the layered material platinum diselenide (PtSe₂) which exhibits a transition from a semi-metal in bulk to a semiconductor for a few layers, allowing band gap engineering through physical thickness. The PtSe₂ film was employed as an ultra-thin metal contact for a vertical hybrid Schottky barrier diode (SBD) formed on crystalline n-type silicon.

Dr Farzan Gity and Prof. Paul Hurley at Tyndall analysed the thickness-dependent electronic properties of the PtSe₂ ultra-thin layers in terms of carrier concentration, type and density, and the nanoscale structure of the PtSe₂ films to provide further understanding of the fundamental electrical properties of the PtSe₂ films and the role of the PtSe₂ in enhancing the spectral response of the PtSe₂/silicon diodes.

This work shows that, compared with other infrared (IR) absorbers based on 2D materials, like graphene or black phosphorus, PtSe₂ is highly advantageous because it can potentially be integrated with standard semiconductor processing due to its low growth temperature of 400°C. In addition, the absorbance of such devices can be tuned through film thickness modulation. Therefore, this work strongly suggests PtSe₂ as a promising 2D material for future IR optoelectronics.

¹ Chanyoung Y, McEvoy N, Riazimehr S, Schneider DS, Gity F, Monaghan S, et al. (2018). Wide spectral photoresponse of layered platinum diselenide-based photodiodes. *Nano Lett*, 18(3): 1794–1800.

Dr Farzan Gity (left) and Prof. Paul Hurley in the Electrical Characterisation Lab at Tyndall, investigating the electrical properties of the two-dimensional PtSe₂ films.



Enhanced bioactive species detection for medical diagnostics

In the development of electrochemical biosensors, the immobilisation and orientation of biorecognition elements onto solid surfaces is a great challenge. The process of immobilisation can decrease the catalytic activity of the attached biomolecules, resulting in decreased performance of the biosensor.

In a paper published in *Electrochimica*², PhD student Vuslat Buk describes how she addressed this issue by preparing a new type of matrix made from gold nanoparticles and carbon quantum dots, which exploits the excellent electrochemical performance of the gold nanoparticles and the remarkable ability of the carbon quantum dots to be chemically modified to attach to a range of biomolecules, without reducing their efficacy towards the detection of the particular target species.

To demonstrate this principle, Vuslat attached the hybrid nanomaterial to microfabricated gold electrodes and then immobilised glucose oxidase onto the new matrix. The resulting biosensor was then used to detect glucose, in a proof-of-concept study.

The new biosensor exhibits excellent sensitivity when compared with many other systems available in the literature and the approach has the possibility to detect a wide range of other bioactive species of significance in medical diagnostics.

The publication by Vuslat Buk and colleagues (Electrochimica Acta 293 (2019) 307-317) introduces the use of quantum dot/gold nanoparticle nanohybrid material into biosensor fabrication to give a reproducible procedure for biosensor production. This bottleneck has limited biosensor commercialisation where a direct fabrication route to produce biosensors with minimum variability is the desired outcome to result in real-world impact.

Prof. Paul Millner,
School of Biomedical Sciences,
University of Leeds

² Buk V, Pemble ME and Twomey K (2019). Fabrication and evaluation of a carbon quantum dot/gold nanoparticle nanohybrid material integrated onto planar micro gold electrodes for potential bioelectrochemical sensing applications. *Electrochim Acta*, 293: 307–317.

Vuslat Buk, winner of the 2018 Postgraduate Research Publication of the Year.



Origin of negative thermal expansion in germanium telluride

Most materials expand upon heating; it is much less common to encounter those that shrink. However, there has been recent interest in materials with negative thermal expansion, driven by technological applications that require materials that do not change their volume with temperature and thus maintain their functionality regardless of temperature. Even though negative thermal expansion is an unusual phenomenon, it is relatively common for materials near lattice instabilities.

In a paper published in *Physical Review B*,³ PhD student Djordje Dangić, Prof. Stephen Fahy and Dr Ivana Savić detail the results of first principles computer simulations undertaken at facilities in Tyndall and the Irish Centre for High-End Computing (ICHEC) to study thermal expansion near lattice

instability in germanium telluride, which is one of the most efficient thermoelectric materials currently known. Thermoelectric materials convert waste heat into electricity. They can be used to power wireless sensors or cool electronic devices. The lattice instability of germanium telluride is thought to be the key to its excellent thermoelectric properties, but also an impediment for its mechanical stability.

The team's calculations explained how germanium telluride exhibits negative thermal expansion near lattice instability. They found that negative thermal expansion is a direct consequence of strong interaction between low frequency lattice vibrations that arise due to lattice instability and other lattice vibrations. The calculations indicated good thermo-mechanical stability for thermoelectric applications, with the methods developed also having potential for the wider design and optimisation of future thermoelectric materials.

³ Dangić D, Murphy AR, Murray ED, Fahy S and Savić I (2018). Coupling between acoustic and soft transverse optical phonons leads to negative thermal expansion of GeTe near the ferroelectric phase transition. *Phys Rev B*, 97(22): 224106.

L to R: PhD student Djordje Dangić, Prof. Stephen Fahy and Dr Ivana Savić.



Pioneering the use of transfer-printing for silicon photonics

Silicon-based photonics is becoming established as an effective manufacturing platform for photonic integrated circuits. Such powerful circuits will enable the high bandwidth and parallelism of photonics to be widely exploited in areas such as data centres and neuromorphic computing systems. However, the integration of the light source remains the key challenge for this technology.

Current strategies to solve this problem include coupling an external laser to silicon waveguides through a grating or by flip chip integration, both of which are slow and sequential processes. Evanescent coupling of wafer-bonded materials is more scalable but limited in thermal dissipation.

In a paper published in the Journal of Lightwave Technology,⁴ Dr Brian Corbett and his team detail how they are pioneering an end-fire coupling approach taking advantage of transfer-printing technology. They demonstrated through comprehensive measurements that this approach is very effective at dissipating heat enabling lasing to >100°C. Furthermore, this strategy is very effective at coupling light into the waveguides.

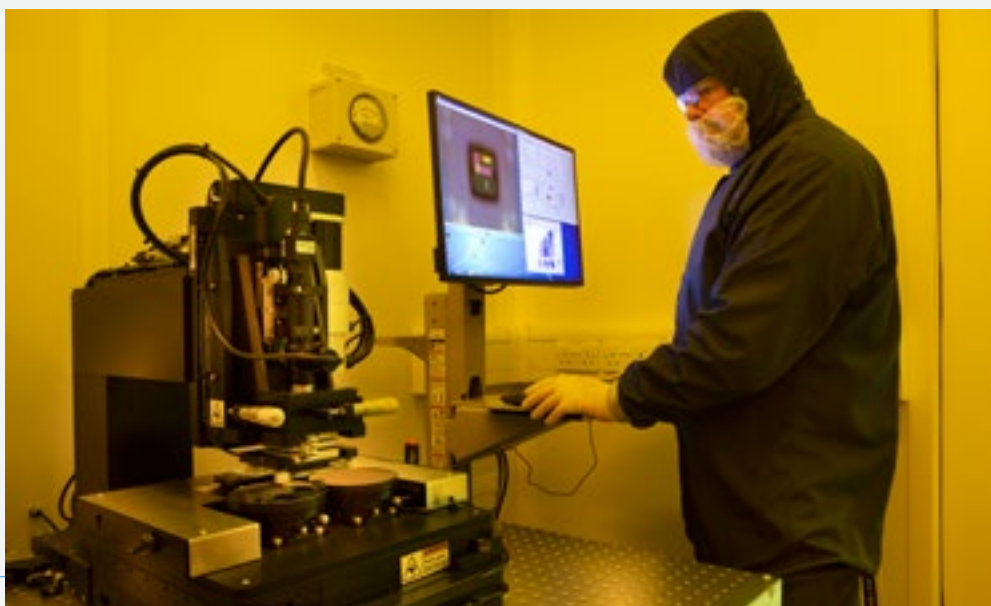
The team believe this is a viable approach to mass implementation of lasers and other components on photonic integrated circuits.

We set up the corporate headquarters for X-Celeprint Ltd in Cork within Tyndall due to its strong focus on photonics, an application of high interest to us. Working with Tyndall in general, and Brian Corbett's group in particular, has exceeded our expectations.

Kyle Benkendorfer,
Founder and CEO,
X-Celeprint Limited

⁴ R Loi, J O'Callaghan, B Roycroft, Z Quan, K Thomas, A Gocalinska, et al. (2018). Thermal analysis of InP lasers transfer printed to silicon photonics substrates. J Light Technol, 36(24): 5935–41.

Transfer printing in the Tyndall cleanroom facility.



Horizon 2020 research success

Since the launch of Horizon 2020, Tyndall has participated in 71 research projects with a total value over €530m, including significant co-funding by industry partners. The investment in our activities is valued at €38m, with an additional €25m funding to our Irish partners, including €16m to Irish enterprises, which will support over 70 industry jobs.

In 2018, 16 new projects were funded, bringing over €9m in funding to Tyndall. The projects span various technology domains and application areas, including medtech, agritech, smart energy and cultural heritage.

Some high added-value wins were Next Europractice eXtended Technologies and Service (NEXTS); pilot lines for Indium-Phosphide (InPulse) and Open-Innovation Photonics Pilot for North West Europe (OIP4NWE); and the AQUASENSE Marie Skłodowska-Curie Innovative Training Network.

This has been a particularly successful year for our participation in core areas in the ICT work programme with significant initiatives in Electronic Smart Systems. These include coordinating SmartVista, and partnering in NANOSMART, ELSAH and SARMENTI projects.

Tyndall secured over €5m in our own right and facilitated a further €2m for five Irish partner companies in eight EU-wide technology innovation projects. Tyndall is in the top 10 European beneficiaries in ICT.

Europractice

The mission of Europractice, supported by NEXTS under Horizon 2020, is to provide European industry and academia with a platform to develop electronic smart integrated systems, from advanced prototype design to volume production. The latter will be achieved by providing affordable and easier access to a wide range of state-of-the-art industry-grade

fabrication technologies and design tools complemented with training and support to the customer in all critical steps.

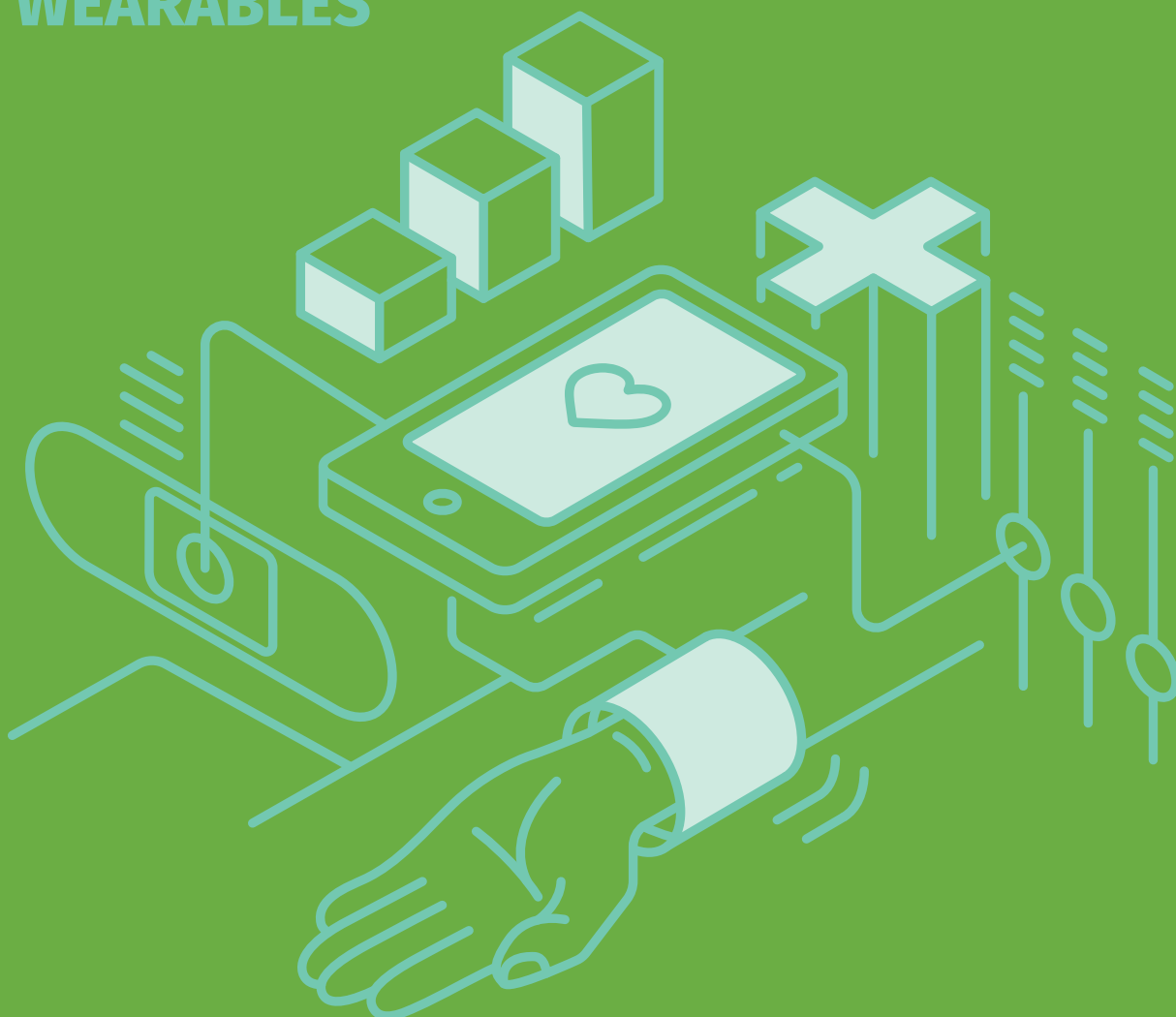
The new partnership builds on many years' experience at imec, STFC, Fraunhofer-IIS, CMP and Tyndall. Europractice has previously supported the European academic sector with design tools and Integrated Circuit prototyping for almost 30 years. Currently, over 600 academic institutes are using these services to train the next generation of engineers for the European industry. Tyndall will add advanced photonic, electronic and microelectromechanical systems (MEMs) packaging and system integration services to the Europractice offering.

Team (L to R): Dr Giorgos Fagas, Martin O'Connell and Dr Cian Ó Murchú.



Industry Engagement

DRIVING NEXT-GEN
HEALTHCARE
WEARABLES



Deep industry collaboration remains a cornerstone of Tyndall's value. Our industry relationships inform our research both for pre-competitive, fundamental scientific research (where we consider far-horizon technology needs across market sectors such as health or energy) and for applied research, which delivers targeted research outcomes and competitive, market-enabling technology on favourable intellectual property (IP) terms. Our industry initiatives are supported by Tyndall Commercial and Research teams, the UCC Office of Technology Transfer, and the entrepreneurship teams at Tyndall and the ESA SSCI.

Dan O'Connell operating the Temescal electron beam metal evaporator with an integrated planetary wafer rotation system using magnetic coupling. This tool enables the deposition of highly uniform metal and dielectric layers used in semiconductor device fabrication.





In 2018, we continued to push the boundaries for collaboration with industry partners, with highlights including:

- **Industry programmes** accounted for €8m, with an additional €3m in industry benefit-in-kind. Direct industry contributions to these programmes totalled >€5m.
- We worked with a **total of 50 industry partners on 70 individual engagements** for research, IP licence and research services (which includes services delivered on our leading fabrication, packaging, test and characterisation facilities).
- **For Disruptive Technology Innovation Fund (DTIF)** research projects alone, 17 private companies came together with

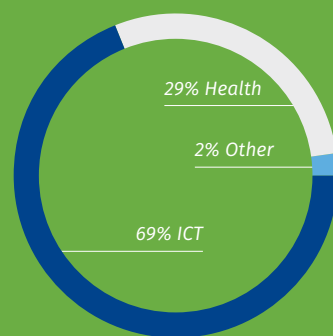
Tyndall to develop technologies for the Health & Wellness, Photonics and Energy sectors.

- There was a significant increase in **industrial training** in photonics fabrication and device packaging, confirming Tyndall as an international leader with over 50 industry researchers and engineering professionals from around the globe attending on-site for specialist training.
- We continued the upward trend from previous years, **where one-third of our industry engagements are now with SMEs**, accounting for 26% of new industry funding in 2018.
- We signed a long-term, **strategic research agreement** with Analog Devices (see page 26).

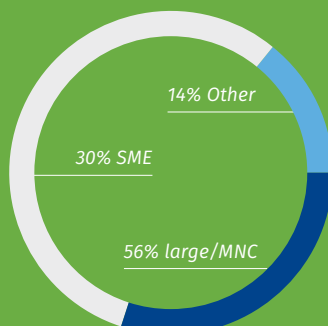
- We reconfirmed our role as long-term, strategic research partner for international industry, with over **40% of the value of our industry collaborations for contracts over €400k**. The nature of these strategic engagements provides our industry partners with continuity of research output and continuous access to leading global research talent.
- **Health and Life Sciences** industry research nearly doubled to 30% of all industry funding, with the remainder coming from the ICT and energy sectors.
- We hosted **40 industry researchers-in-residence** on-site, a growing number of global researchers who collaborate with our research teams and access our state-of-the-art infrastructure.

THE YEAR IN FOCUS

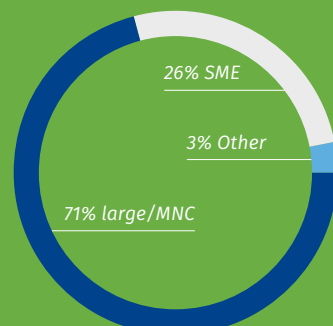
New industry research spending commitment 2018 by application sector:



New industry research spending commitment 2018 by company size:



Number of industry clients 2018 by company size:



Impact of Tyndall's industry partner network

Tyndall's success in the first round of DTIF awards in 2018, with four successful bids, demonstrates the institute's role as the leading industry research collaboration centre for ICT in Ireland.

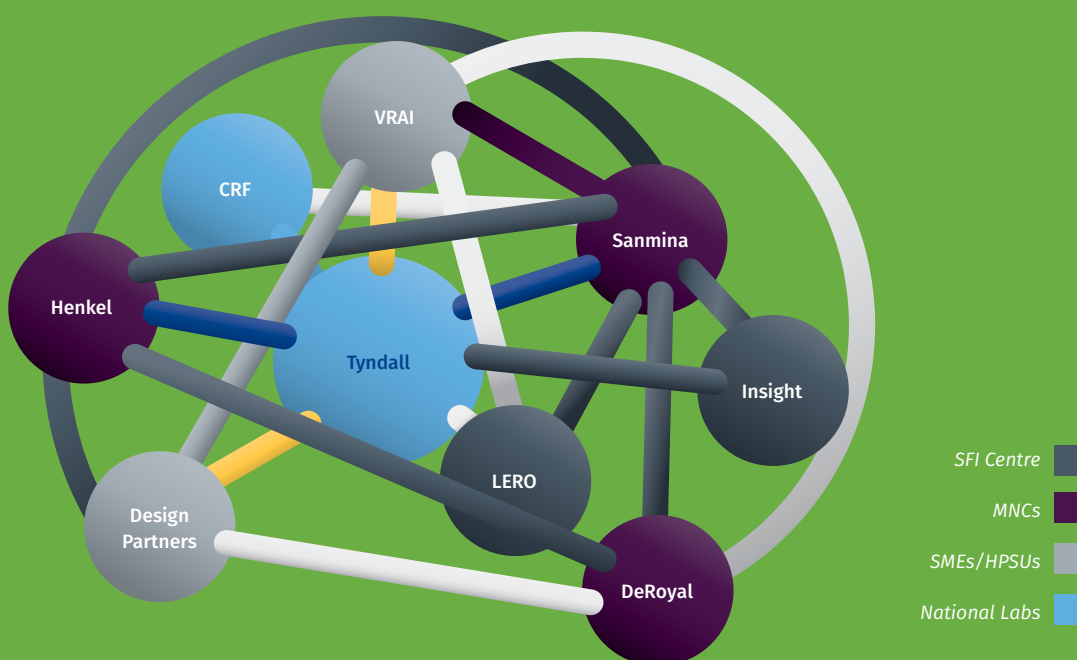
The DTIF Holistics programme was the largest national award in 2018 at €7.4m, comprising a network of 14 collaborators (including two national research labs; four multinational corporations (MNCs); five SMEs/high potential start-ups (HPSUs), one EI/IDA-funded technology centre and two SFI-funded research centres), illustrating the breadth and

depth of Tyndall's innovation ecosystem.

The illustration below shows just one of five new collaborative networks created in the Holistics programme. This disruptive Health and Wellness programme brings together several of Tyndall's strategic ICT-for-Health group's partners to contribute expert building blocks, driven by our Academic, Business, Clinical & Design thinking (ABCD) engagement model for health-related research. The programme also brings SME and MNC partners together in the supply chain, providing SME access to global decision-makers in the multinational sector and new opportunities for growth.

Impact of deep-tech output as licensed IP

In 2018, we completed a new licence deal for our groundbreaking magnetic components on silicon (integrated magnetics) technology, **bringing the licensing value to date of this single technology to over €5m**. This integrated magnetics technology has previously been the subject of licences and a joint patent with global industry leaders in the smartphone market, and this most recent case confirms Tyndall's leadership position in delivering value-driven magnetics and power supply technologies for everyday high-tech products.





Entrepreneurship and start-up impact

Our entrepreneurship team grew in 2018 to combine the expertise of our Commercial Centre, the UCC Office of Technology Transfer, our Entrepreneur-in-Residence and the ESA Space Solutions Centre and BIC.

In 2018, we saw rapid growth of the number of new ventures in formation and incubation, as well as examples of scaling and acquisition, including:

- Eleven potential technology spin-outs working on commercial validation and minimum viable product (MVP) demonstrators.
- Tyndall spin-out SensL was acquired by global semiconductor firm ON Semiconductor to extend its market leadership in automotive sensing applications for advanced driver-assistance systems (ADAS) and autonomous driving, with expanded capabilities in imaging, radar and light detection and ranging (LiDAR).

- Eight new start-ups were supported by the ESA Business Incubation Centre, part of ESA Space Solutions Centre Ireland, an Enterprise Ireland-supported consortium led by Tyndall and including MaREI, NUI Maynooth and Athlone Institute of Technology. Five of these are hosted at Tyndall's incubation space, Lee Mills House.
- One of these ESA BIC-supported companies, the environmental technology start-up ApisProtect, secured €1.5m in venture funding with a commitment to expand its team to 25.
- A group of external, market-focused entrepreneurs began engagements with three research groups with specific spin-out objectives for 2019.

Analog Devices multiannual research agreement

Acknowledging Tyndall as one of Europe's leading technology research centres, Analog Devices Inc. (ADI) signed a multiyear research agreement. This agreement further strengthened our relationship with ADI, spanning four decades of research and development collaboration. This long-term and strategic partnership ensures continuity of innovative research capability as well as access to our world-class talent.

At the signing of the strategic research partnership between Analog Devices and Tyndall were (left to right) Peter Smyth, commercial director, Tyndall; Denis Doyle, vice president and general manager, Analog Devices; Prof. William Scanlon, CEO, Tyndall; and Leo McHugh, vice president, Global Industrial Business Unit, Analog Devices.



Technology transfer

UCC's Technology Transfer Office (TTO) manages Tyndall's intellectual property portfolio and facilitates the commercialisation of our innovative scientific and engineering research. It was another record year for research and innovation with 10 licences, options and assignments (LOAs) executed, 30 invention disclosures, and one start-up established. In 2018, TTO was delighted to be ranked joint highest in terms of LOAs executed and spin-outs/start-ups established in Knowledge Transfer Ireland's Annual Knowledge Transfer Survey 2017. Dr Rich Ferrie also joined the team as TTO director.

Awards

UCC's ICT Invention of the Year was awarded to '**Battery Life Magnetics Technology**', developed by Tyndall researchers led by Prof. Cian Ó Mathúna.

Licences, options and assignments

- Licence of **Magnetics on Silicon** for use in semiconductor product manufacture.
- Licence of a **Pacing Integrated Circuit** for use in implanted pacemakers to pace the heart and provide a direct method of measuring the electrical impedance of the heart.
- Licence of a **Neurostimulation Integrated Circuit** for use in neurostimulators modulating the nervous system to provide pain relief via electrical impulses which disrupt pain signals travelling between the spinal cord and the brain.
- Evaluation and Option Licence of a patented **Linear Burst Mode Receiver**.
- Evaluation and Option Licence of a **Phase Modulator of Optical Signal** for use in creating phase-modulated signals in multimode interference couplers, enabling advanced modulation signals required for optical communication systems.
- Assignment of **Design of Compact 915 MHz Antenna** for integration in wearable sensing applications including health and IoT applications.
- Assignment of **Photonic Package** comprising an encapsulated micro-optical bench, a photonic chip, electrical and optical interconnects and a mechanical enclosure.

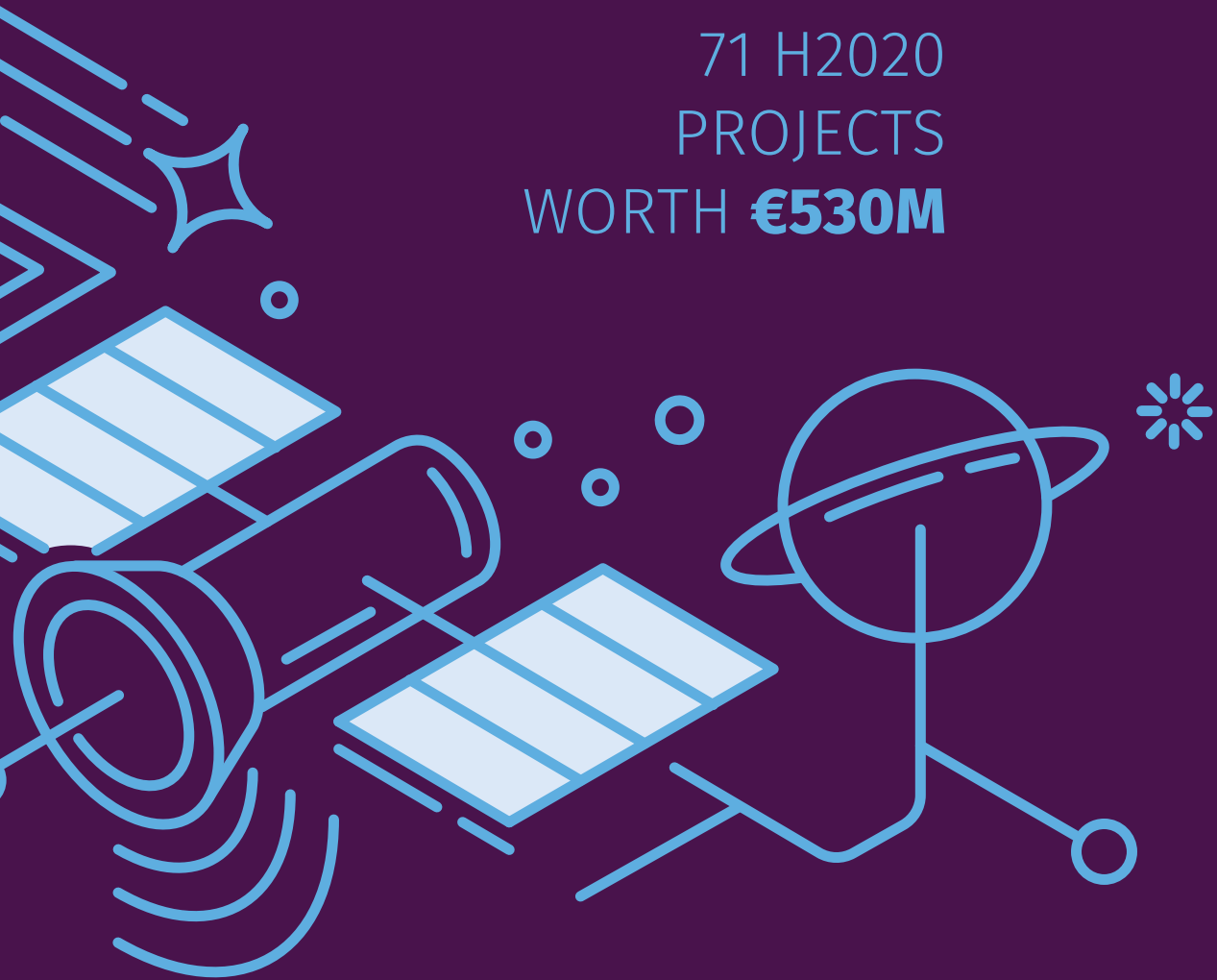
L to R: Eleanor Cornish, UCC TTO; Prof. Cian Ó Mathúna, head of Micro and Nano Systems Centre, Tyndall; and Dr Anthony Morrissey, UCC TTO, with the UCC ICT Invention of the Year Award for magnetics on silicon technology.



International reach



71 H2020
PROJECTS
WORTH **€530M**





PwrSoC, founded by Tyndall's Prof. Cian Ó Mathúna in 2008, celebrated its 10th anniversary with a workshop in one of the world's leading semiconductor manufacturing centres, Hsinchu, Taiwan.

The event gathered academic and industry experts to discuss the challenges and opportunities in technology, design, and manufacturing necessary for advancement of miniaturised integrated power conversion and management solutions.

The 2018 PwrSoC workshop confirmed the strong advancement of the critical technologies necessary to commercialise miniaturised power management semiconductor circuits integrated with associated power passive components.

At the event, Tyndall's Integrated Magnetics Team presented their single inductor, coupled inductor and transformer designs optimised for ~30MHz application. The devices used a solenoid construction with a laminated Co-Zr-Ta-B thin film magnetic core. Electrical test of the completed devices revealed a leading edge Q factor for integrated single inductors (Q~24) at 30MHz.



EnerHarv was founded in 2018 by the Energy Harvesting Committee of the Power Sources Manufacturers Association, led by Tyndall's Mike Hayes who is currently president of the PSMA board of directors and Brian Zahnstecher from PowerRox.

The objective of the event was to be a focal point for a community of experts and users of energy harvesting and related technologies to share knowledge, best practices, roadmaps and experiences and to create opportunities for collaboration and provide reliable power sources for the trillion sensor economy predicted for 2025.

Eighty-one international attendees enjoyed presentations, demonstrations and interactive panel discussions at the inaugural event. While attendees arrived with a passion for energy harvesting and power management solutions for IoT applications, they left with a wealth of additional knowledge and valuable collaborative relationships.



Tyndall hosted the 18th IEEE International Conference on Nanotechnology in Cork with 373 attendees from 41 countries. Chaired by Prof. Aidan Quinn, this flagship conference on nanotechnology focused on promoting and disseminating research in key strategic areas that will enhance Ireland's global competitiveness. Topics ranged from fundamentals in nanomaterials and nanofabrication to development of nanosensors and nanoelectronic devices.

IEEE NANO 2018 featured experimental contributions as well as modelling and simulation, with contributions from both academic and industry-based researchers. The thematic focus was, "Nano-Enabled Smart Things", new materials, devices and systems that can benefit humanity through applications in information and communications technologies, energy, healthcare, food and environment.



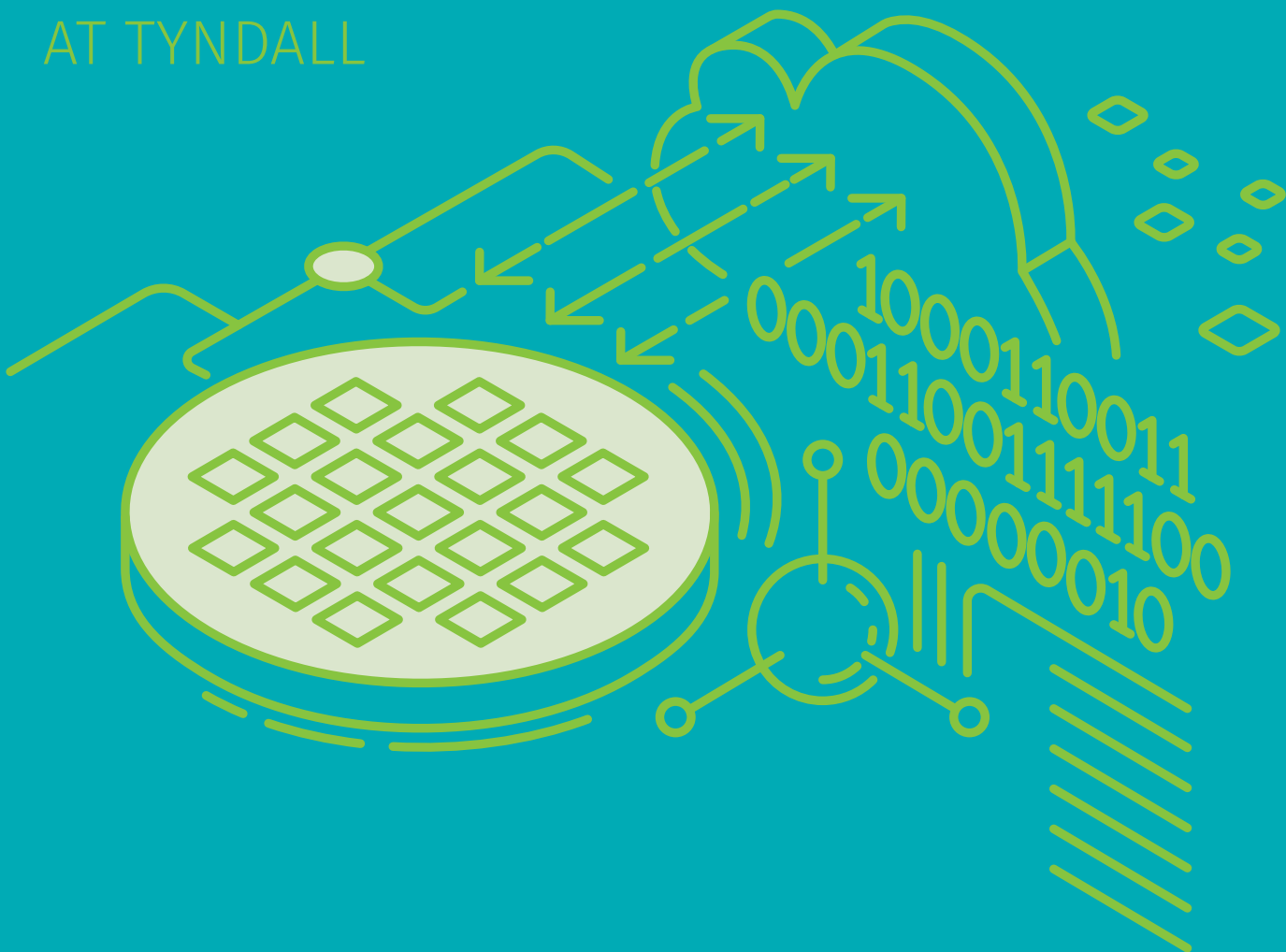
Photonics West is the world's largest photonics technology event with more than 22,000 attendees demonstrating developments in areas such as optical communications, medical technologies, AR/VR and autonomous vehicles, all powered by photonics.

As part of our strategy to raise our international profile, established a pavilion at Photonics West 2018 in partnership with Ireland's scientific and economic-focused Government agencies – SFI, EI and IDA – and a number of Irish SMEs and emerging start-up companies: mBryonics, Eblana Photonics, Pilot Photonics, Luz WaveLabs, PICDraw and SLEDs.

Our presence at the event enabled us to directly engage with potential new industry partners and existing industry partners to strengthen the Tyndall and IPIC brands, and demonstrate Ireland as a leading location for photonics research and commercialisation. In addition, it provided our partner SMEs with a platform to secure sales by attracting new customers and meeting existing customers.

Agency-funded centres

ROCKLEY **PHOTONICS**
LAUNCH R&D CENTRE
AT TYNDALL





SFI Research Centre IPIC secured phase 2 funding of €26m in 2018 that will not only sustain the centre to 2025, but will also drive growth to over 200 researchers and strengthen its position as one of Europe's top photonics integration research centres.

In 2018, we launched our new strategy, IPIC 2025, which is built on three pillars: research excellence, transition to market, and the IPIC Academy. Key elements include:

- Four cross-centre collaborative platform projects targeted at delivering game-changing technologies in the areas of:
 - Monolithic and heterogeneous integration.
 - Packaging and hybrid integration.
 - Coherent communications to the network edge.
 - World's smallest integrated imaging system for guided surgery.
- Expanded prototyping capability and the establishment of manufacturing pilot lines in partnership with equipment suppliers and end-user companies.
- Broader industry engagement and IP access models with a target of 40% of activities with SMEs.
- Structured training programmes, including the Photonic Integration and Advanced Data Storage (PIADS) Centre of Doctoral Training in partnership with Queen's University Belfast and Glasgow University, which will train 75 PhDs.

2018 highlights

- In total, 83 PhD students successfully completed their training in IPIC phase, with 60% moving to industry as their first destination.
- New partnerships with AuriGen Medical and Raydiant.
- Secured industry income of €4.6m and international funding of over €21m, mainly from EU.
- Rolled out Summer Bursary Programme and PRISM exhibition showcasing the science of art and light.
- Prof. Peter O'Brien was awarded the SFI Best International Engagement Award.



Prof. Paul Townsend, head of photonics at Tyndall and director of the IPIC SFI Research Centre, with Magaly Mora, research assistant at Tyndall and operations manager at the PIXAPP Photonic Packing Pilot Line, verifying the quality of wire bonding 1310 nm LD chip to submount in the PIXAPP Training Package (zoom magnification 100x).





El Technology Centre MCCI has established itself as a single point of contact for access to high-calibre academic research in the field of microelectronics in Ireland and with a vision to 'be the number one microelectronic circuits research centre globally, for industrial and academic collaboration by 2025', we are well on the way to achieving that vision.

The centre is organised around four key research pillars:

- Transceivers.
- Precision circuits.
- Power management.
- Digital circuits.

2018 highlights

- Received a successful centre review, supported by EI and the IDA, which highlighted our impacts, including the creation of 458 jobs and over €27m in additional revenue generated at collaborating companies.
- 25 publications in 2018, with 7 at Tier 1 conferences.
- 50th researcher transferred to industry.
- Dr Ivan O'Connell won the Science Foundation Ireland Award for Industry Partnership, which recognises his collaboration with industry.



Dr Ivan O'Connell (centre) received the SFI Industry Partnership Award from Prof. Mark Ferguson, Director General SFI, and Dr Orlaigh Quinn, Secretary General of the Department of Business, Enterprise and Innovation, at the annual SFI Science Summit.





The International Energy Research Centre (IERC) at Tyndall works in collaboration with industry partners to deliver high value energy solutions to the Irish economy. We do this by translating industry innovation needs into well-defined and executable research objectives. The research outputs provide evidence of the performance and cost-effectiveness of novel technology options that can support enhanced delivery of energy policy.

In 2018, we executed collaborative projects with 20 industry partners, and increased efforts to diversify income streams through activity in Horizon 2020, DTIF, EI and SFI programmes and the Climate Action Fund.

From the end of 2018, IERC ceased to be part of the Enterprise Ireland Technology Centres Programme, and transfers its reporting responsibilities to the Department of Communications, Climate Action and Environment. This will encourage greater integration and cross-disciplinary working with other teams within Tyndall, while maintaining its unique position as a predominantly industry-facing energy research centre.

2018 highlights

- Involved in 10 collaborative research projects with a total value of over €5.5m, including two Horizon 2020 projects and an International Energy Agency Annex.
- Won two new Horizon 2020 projects, with just under €1m of income to the IERC (total value of projects across all partners was €11m).
- Led a successful collaborative proposal to the DTIF worth €3.5m on community energy trading involving blockchain technologies.
- Piyush Verma selected as a World Energy Council Future Energy Leader – through this work he established a Blockchain in Energy network in Ireland.
- Made a successful bid to the Sustainable Energy Authority of Ireland Low Carbon Framework for consultancy support to policy development.
- Added new research domain skills to the team in the areas of energy markets and policy analysis, building energy modelling and thermodynamic systems modelling.



TECHNOLOGY CENTRE
SUPPORTED BY
ENTERPRISE IRELAND



L to R: Dr Beth Massey, head of research at IERC, with Piyush Verma, senior energy market analyst at IERC, and Molly Webb, founder and CEO of Energy Unlocked at a Blockchain in Energy event at Tyndall.





Launched in September 2016, ESA Space Solutions Centre Ireland supports businesses with innovative ideas for using space technology to develop new products and services in a non-space environment. To date, we have 12 companies signed up to the BIC and have funded four technology transfers.



2018 highlights

- Eight start-ups selected to join ESA BIC in areas that range from optimising beekeeping to internet security.
- A number of these companies are fundraising, including ApisProtect, who secured €1.5m funding in 2018.
- Four technology transfer projects funded.
- We supported Skytek in their diversification into the marine sector through paperless vessels. They had a very successful demonstration trial on a bulk tanker passage from Venice to several Chinese ports, leading to negotiations to install on approximately 200 vessels. Expected to generate several millions in annual revenues.
- Supported Skytek in developing a real-time marine insurance risk analysis tool in partnership with Aon Ireland, which is expected to generate several millions in annual revenues.

L to R: Minister of State for Training, Skills, Innovation, Research and Development John Halligan TD with Johann-Dietrich Wörner, director general of ESA, and David Gibbons and Ian Kerins of Thalman Health, during the director general's visit to Tyndall.





The €40m SFI VistaMilk Centre, which launched in September 2018 with a team of over 200 scientists, aims to be an agent of growth for the Irish dairy industry by being a world leader in fundamental and translational research for precision pasture-based dairying.

The centre represents a unique collaboration between agri-food and ICT research institutes with leading Irish and multinational food and ICT companies. It is hosted by Teagasc, in partnership with Tyndall, the Telecommunications Software & Systems Group at Waterford Institute of Technology and the Insight Centre for Data Analytics.

At Tyndall, we are building capacity by developing smart sensor systems to address key real-time challenges, identified by food and ICT stakeholders. The value-added partnerships in the VistaMilk Centre will go beyond the state-of-the-art in agritech programmes and will be a catalyst for global growth in the agritech sector.



2018 highlights

Three EU projects funded:

- AQUASENSE: Innovative network for training in water and food-quality monitoring using autonomous sensors and intelligent data gathering and analysis.
- SARMENTI: Smart multisensor embedded and secure system for soil nutrient and gaseous emission monitoring.
- DEMETER: Building an interoperable, data-driven, innovative and sustainable European agri-food sector.

L to R front row: Prof. William Scanlon, Tyndall CEO, and Prof. Gerry Boyle, Teagasc director, with (back row) Dr Alan O'Riordan, senior research fellow at Tyndall, and Prof. Donagh Berry, VistaMilk director.





Founded in 2015, CONNECT is a €60m SFI research centre for future networks and communications, hosted by Trinity College Dublin. At Tyndall, we lead the centre's 'Low Energy Network' theme, researching smart systems, smart sensors, energy generation and energy storage technology.

The result of phase two submission will be released in 2019, and if this is successful it will allow us to progress our mission to deliver research on how to reliably power the trillion sensors required for the future IoT in a sustainable manner.



2018 highlights

- Led the development of the Low Energy Network research agenda (in preparation for the centre's Phase 2 application), with exciting new initiatives with CONNECT partner institutes focused on the sustainable IoT.
- Won the SFI Industry Partnership Award, which recognised the impact of the multiple industry projects throughout the year.
- Two 'Marie Curie Skłodowska' fellows joined the Tyndall team in 2018, adding research depth in Atomistic Modelling.
- Made an impactful contribution to CONNECT's 2018 public engagement programme; Mariusz Wilk presented with one of two inaugural CONNECT Education and Public Engagement Awards.

PhD student Mariusz Wilk testing his wearable human motion tracking system, which incorporates low-power monocular vision and inertial sensor technology and runs a state-of-the-art sensor fusion algorithm that he has developed.





The vision of SFI centre CONFIRM is to transform and grow Irish manufacturing by integrating intelligence within products, machines, production systems and supply chains. This transformation to smart manufacturing – the intelligent, real-time orchestration and optimisation of physical, digital and business processes within factories and across the entire value chain – is defining the next industrial revolution.

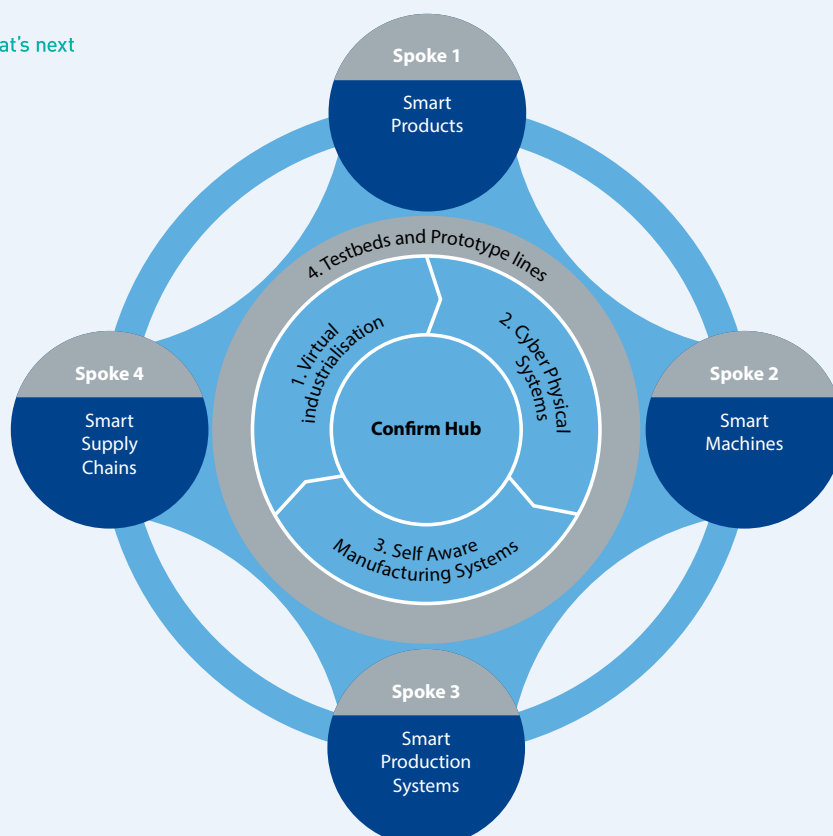
At Tyndall, our research involves smart products, self-aware manufacturing systems and testbeds and prototype lines, which all form the areas of engagement that CONFIRM has established with industry partners to address this sea change in manufacturing.

2018 highlights

- Over 116 journal publications in 2018.
- Operations team established involving seven new hires.
- €3m non-Exchequer, philanthropic and university funding secured to establish the CONFIRM headquarters and testbed facility in Park Point, Limerick. This will house the Digital Factory 4.0 Ireland (DF4I), which will be a sector-agnostic facility to enable Irish industry and academia carry out smart manufacturing research at a systems level.
- Carried out 65 company engagements.
- €2m cash secured from industry for targeted projects.

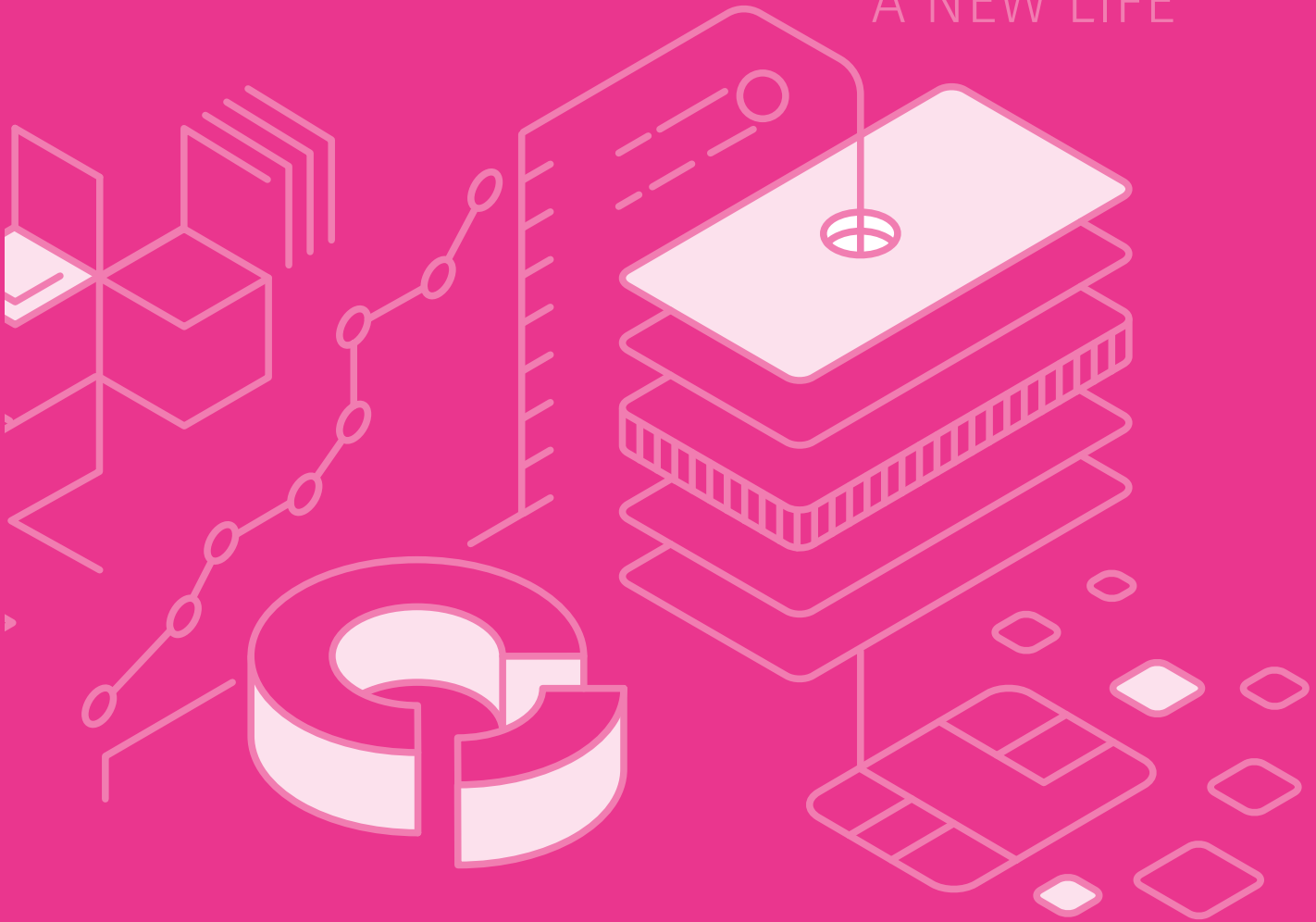


Hosted by UL



Specialty products and services

GIVING
CMOS TECH
A NEW LIFE



We continued our substantial capital programme for infrastructure upgrade during 2018 with the purchase of the following tools:

Two plasma etchers

These will replace the existing tooling for etching of a family of materials including InP and related compounds (GaAs and InP with ternary and quaternary III-V compositions and GaN) as well as plasma etching of dielectric materials and difficult metals such as gold, magnetic alloys and platinum.

Aluminium nitride cluster tool

This multichamber tool will significantly enhance our capabilities for piezoelectric research, with applications in health, energy, communications, agritech and environment.

Hydrogen fluoride vapour etcher

This is an essential tool for etch release of MEMs structures and free-standing nanowires used for next generation electronic transistor research.

Automated linewidth measurement tool

Used for wafer-scale mapping of patterned feature sizes and wafer-scale surface profilometers, these are key tools for process control as we move to higher technology readiness level (TRL) activities and collaborate with more industry research partners within the cleanroom.

Developing new capabilities with the new tools

Scanning capacitance microscopy (SCM) using atomic force microscopy (AFM) extracts two-dimensional doping profiles in semiconductor devices.

The SCM image on the right in Figure 3, captured on our new Bruker Dimension Icon System, is a cross-section of a PNP bipolar transistor, showing emitter, base, collector and isolation, which are not visible in the original optical cross-section on the left. The full carrier concentration range is seen simultaneously with 30 nm. lateral resolution.

This new capability will be invaluable in the development of the next generation nanoelectronics, silicon carbide-on-silicon and photonic devices being developed at Tyndall. This is also already generating interest as a commercial service offering.

Figure 3: SCM image showing a cross-section of a PNP bipolar transistor.



The first European DPA facility for electronic components

Home to the ESA SSCI and an internationally recognised test facility, Tyndall was the first laboratory in Europe to be awarded the DPA (Destructive Physical Analysis) accredited space component analysis service under ISO17025. Driven by the needs of the traditional and new space sectors, this critical European capability also addresses the stringent test requirements of emerging sectors in autonomous systems (e.g. robotics, autonomous vehicles).



Elionix ELS-G100 100kV Electron Beam Lithography System

This specialised analytical service will assist Irish companies developing high-reliability systems, as well as attracting Irish and European partners requiring accredited testing facilities for components specifically for space flight hardware, satellites, flight guidance and scientific instrumentation.

The ISO17025 accreditation builds on Tyndall's existing expertise in the European space component industry and provides formal independent and international recognition of Tyndall as a leading test facility for high-reliability space components.

Advanced 100kV Elionix ELS-G100 Electron Beam Lithography System

This advanced lithography tool will deliver to Tyndall the capability of patterning structures down to less than 6nm over substrates up 8" diameter. This equates to being able to pattern structures that are less than 40 atoms wide. It will be an invaluable tool as we move increasingly into structuring materials at the atomic level for the next generation of electronic and photonic device development.



The new Bruker AFM Dimension Icon System in operation.



Graduate education



MAKING
ELECTROCHEMICAL
BIOSENSORS
A REALITY

Student achievements 2018



Marcelo Saito Nogueira

PhD student, Biophotonics

Marcelo received the Best Student Paper Award at SPIE Photonics Europe Conference on Biophotonics for his paper on 'Diffuse reflectance spectroscopy for determination of optical properties and chromophore concentrations of mice internal organs in the range of 350 nm to 1860 nm', which was also awarded runner-up in the Tyndall 2018 Postgraduate Research Publication of the Year competition. He received third prize at the Siegman International School on Lasers, Optical Society of America Foundation for his work on 'Multimodal optical spectroscopy for more accurate surgical guidance and disease detection' and was awarded fourth prize (honourable mention) at the Biophotonics and Imaging Summer School 2018 for his paper on 'Broadband diffuse reflectance spectroscopy for gastrointestinal interventions and oral cancer screening'. Among the 15 presenters at SPIE BIOS19 (SPIE Photonics West 2019), Marcelo was selected for the special three-minute poster session competition.



Amy Kirwin

PhD student, Photonics Theory

Was one of four SEFS postgraduate Students who won SEFS Travel Bursaries in 2018 for academic ability. Amy received the award for her achievements in Physics and used the bursary to attend the 15th ETSF Young Researchers' Meeting 2018. The Bursaries are awarded to PhD students to enable them to present their work at International Conferences or facilitate the training of students who wish to acquire skills that are essential for their academic development, but which they cannot otherwise receive in UCC



Niamh Kavanagh

PhD student, Photonic Systems

Niamh was named, by Silicon Republic, as one of '10 inspiring women in science you need to follow' and as one of 'The Community Builders: 13 women helping women in STEM'. This was in acknowledgement of her work as an outstanding science communicator; for her outreach and public engagement work; and for being a passionate supporter and advocate for diversity, inclusion and equality in STEM. In March, she co-founded UCC's EPONA (Equal Physics Opportunity Network in Academia). Niamh was one of the organisers for the first International LGBT STEM day in July, an event which reached 75 million people worldwide. She also featured in a television documentary about gender equality called *The Big Picture: A Woman's World*, viewed by over 220,000 people in November 2018.



Andrea Liliana Pacheco Tobo

PhD student, Biophotonics

Andrea received a SPIE optics and photonics education scholarship and was awarded a travel grant for the OSA Biophotonics Congress in the USA. Andrea's poster on 'Near infrared light propagation modelling of infant thorax with different light source-detector configurations' received First Place Poster Award at Photonics Ireland Conference. She was awarded Second Place Poster Award at the Biophotonics and Imaging Graduate Summer School.



Natalia Canas Estrada

PhD student, Photonics Systems

Natalia received the IEEE Photonics Society outreach grant to develop a five-stage workshop entitled 'Family STEM zone' featuring activities and explanations of photonics, including virtual reality, kaleidoscope and UV light. The workshop was part of Culture Night 2018.



Vuslat Buk

PhD student, Life Science Interfaces

Vuslat won the Tyndall 2018 Postgraduate Research Publication of the Year for her publication in *Electrochimica Acta* 293 and received a Royal Society of Chemistry fee waiver at the 7th Baltic Electrochemistry Conference: Finding New Inspiration for her presentation on 'New nanomaterial-based, microfabricated, miniaturized electrochemical sensors for the detection of glucose'.



Mariusz Wilk

PhD student, Wireless Sensor Networks

Mariusz received the inaugural CONNECT Education and Public Engagement Award for his contribution to the centre's outreach programme. The award citation highlighted, in particular, Mariusz's development of smart farming demos to prompt conversations with the public on the usefulness of the IoT for agriculture.



Stefano Moroni

PhD student, Photonics Epitaxy and Physics of Nanostructures,

Stefano was awarded the BOC Gases Bursary for his research on the use of site-controlled pyramidal quantum dots as sources of entangled photons to be used for quantum information.



Ian Seymour

PhD student, Electrochemical Materials and Energy

Ian won Best Student Oral Presentation at IEEE Nano for his presentation entitled 'Interdigitated nanowire electrode arrays for enhanced electrochemical sensing'.



Saroj Kanta Patra

PhD student, Photonics Theory

Saroj was awarded runner-up prize in the BOC Bursary for his research investigating the electronic and optical properties of III-V nanostructures. Saroj was also awarded an IEEE student travel bursary to attend the IEEE Photonics Conference in Reston, VA, USA in 2018.

PhD vivas 2018

Silviu Bogusevski

'Theory and optimisation of metamorphic photonic devices'

Ludovic Caro

'Design and fabrication of single-mode tunable lasers for regrowth-free monolithically integrated photonic circuits'

Tomás Clancy

'Nanomaterial design and fabrication for energy storage'

Niamh Creedon

'Sensing at nanostructures for agri-food and environmental applications'

Yann Donnelly

'A divider controller for optimised fractional-N frequency synthesizer spectral performance in the presence of loop nonlinearities'

Jan Kegel

'Fabrication and characterisation of ZnO-based water splitting devices by atomic layer deposition and hydrothermal synthesis'

Moises Jezzini

'Microwave design of multi-layer interposers for the packaging of photonic integrated circuits'

Harry Manley

'An evaluation of some commercially-available thin TiO₂ films and TiO₂ films grown by atomic layer deposition for potential photocatalytic applications'

Shane McDermott

'Correlated electron transport across atomic and molecular tunnel junctions'

Stefano Moroni

'Site-controlled quantum dots as sources of quantum light'

Ethel Noonan

'Investigation of solution-phase and on-chip binding of C-reactive proteins and antibodies'

Shahab Norouzi Alam

'Optimisation of high efficiency UV and visible light sources, utilising lateral localisation in InAlN and InGa_N based nanostructure devices'

Ben O'Shaughnessy

'Dynamics of swept source lasers'

Pietro Pampili

'Fabrication and characterisation of UV-LEDs'

Catherine Ryan

'The design, synthesis and characterisation of chitosan-based interpenetrating polymer networks and thin film systems'

Dzianis Saladukha

'Semiconductor materials and devices for 2 micron generation'

Shauna Scanlon

'Development of a multi-parameter sensing system for Process Analytical Technology (PAT) application in the food and beverage industry'

Han Shao

'Nanostructure materials based supercapattery for next generation pacemaker'

Equality, diversity and inclusion

At Tyndall, we are committed to working towards equality of opportunity for all. We are home to 450 staff and students from 52 countries, creating an engaging, multicultural and diverse working environment. In 2018, Bernadette Guiney was appointed as our first Equality, Diversity and Inclusion (EDI) champion.

At our annual Internal Conference, Bernadette delivered a powerful and impactful presentation on the theme of 'Words Matter – Using Inclusive Language'. The talk covered the importance of the use of inclusive language and how it can shape a broader and inclusive work environment. The presentation won the prize for best talk. In November, we celebrated cultural diversity with 30 nationalities, showcasing their national culture, traditions and customs in an informative and fun way. From this event we developed a diversity calendar with fun photos from the day. We also partnered with our colleagues in UCC by hosting talks and seminars on topics including LGBT+ and unconscious bias.

Tyndall Celebrates Cultural Diversity in the Workplace, November 2018.

Empowering Women @ Tyndall

The Empowering Women @ Tyndall programme was launched in 2016 to support our female staff and students to reach their full potential.

The committee is made up of a gender diverse group from all areas of Tyndall, and together they defined a plan to involve, engage and support diversity across the institute.

The committee has organised talks from inspiring leaders; celebrated Equality Week and International Women's Day; participated in iWish; and hosted four students as part of the Teen-Turn initiative to help provide clarity to Leaving Certificate students around course decision-making and inform participants on education and career options in STEM.

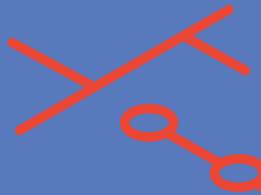
Athena SWAN

We are delighted to announce that we will be making an application in 2020 for an Athena SWAN Bronze Award. The Athena SWAN Charter (established in 2005) focuses on recognising advancement in gender equality: representation, progression and success for all.

The application process will include a self-assessment (where we are now) and an action plan to achieve equality of opportunity for all. This will be a key focus within our Tyndall 2025 strategy.



Public engagement



BIOPHOTONIC SENSOR TO TREAT **ATRIAL FIBRILLATION**



2018 was another successful year for Tyndall's promotion of STEM through public engagement and outreach activities. We aim for high-quality interactions which deliver lasting impact and are committed to engaging with groups previously underserved by STEM activities, such as those in lower socioeconomic groups, females and adults aged 30 and over.

We were involved in many activities over the year including festivals, open days, work placements and school visits. Our highlights include the following:

MakerDojo

Led by our Maker-in-Chief, William Knott, MakerDojo engaged with 3,000 members of the general public, many of whom were not previously engaged with STEM activities, at 12 family and art festivals throughout Ireland.

Culture Night

One hundred and sixty members of the public had the chance to meet with Tyndall researchers to discover our cutting-edge research when we opened our doors for Culture night in September. Attendees enjoyed interactive demonstrations and had the opportunity to attend talks and to witness how artist Angela Gilmour merged art and science in 'The Sum of All Parts' exhibition.

Natalia Cañas-Estrada, a PhD student in our Photonics Systems Group, developed a Family STEM Zone where audiences learned how to make kaleidoscopes, examine ultraviolet (UV) light and make objects glow. They also had the chance to learn about photography and take a virtual reality tour through our solar system.

Young students attending Engineers Week activities at Tyndall.



Prism: The Art and Science of Light

As 2018 drew to a close, IPIC worked closely with The Glucksman Gallery in UCC and artist, Emer O'Boyle, on their new exhibition celebrating the art and science of light. As academic partner for the exhibition, IPIC commissioned Emer to build 'The Gaposchkin Chandelier', which comprises 603 individual coloured test tubes each containing the signature of students and staff across Tyndall and UCC. The chandelier celebrates our commitment to addressing gender balance across the institute.

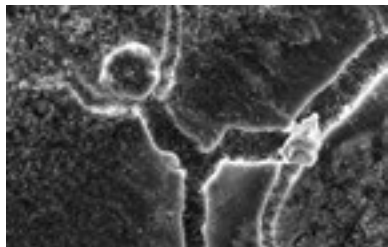
2018 highlights

- We engaged with 530 primary school and 800 secondary school students.
- 143 Transition Year students completed work experience programmes at Tyndall.
- MakerDojo participated in 12 festivals throughout Ireland, engaging almost 3,000 people.
- 134 people attended MakerDojo workshops at Tyndall.
- 12,000 people participated in Cork Science Festival organised by the Lifetime Lab, Tyndall, IPIC, CONNECT, APC Microbiome Ireland, MaREI and INFANT.
- 10 positions were awarded for the IPIC Undergraduate Student Summer Bursary Programme.

The Gaposchkin Chandelier installed at The Glucksman-Gallery in UCC.



Scientific Image Competition winners



Nano-man

Adria Garcia

Materials Chemistry and Analysis

The purpose of this experiment was to grow GeSn nanowires by chemical vapour deposition with the presence of oleylamine and oleic acid as wire protectors, but an excess of those led to the creation of this little creature.

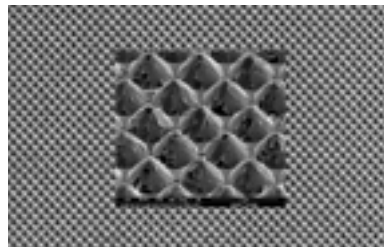


Phantom

Andrea Pacheco

Biophotonics

We are developing realistic optical tissue phantoms to make bench-top measurements to aid us in developing a novel clinical device to non-invasively assess the lung function in preterm babies.

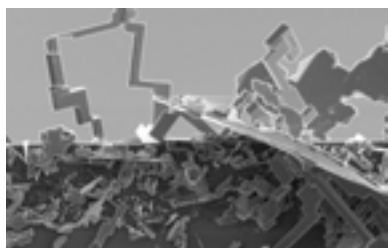


Mesmerising hills

Michael Schmidt and Lynette Keeney

EMAF / AMSG

Single-phase, room temperature magnetoelectric multiferroic materials are of considerable interest for data storage technologies. This scanning electron microscope (SEM) image shows this material grown by liquid injection atomic vapour deposition on patterned sapphire to influence the direction of properties.

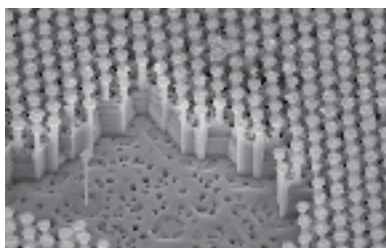


Abstract nano-ruins

Fionán Davitt

Materials Chemistry and Analysis

This image shows a SEM image of some abstract SnSe₂ nanostructures, grown through the use of chemical vapour deposition. This image was taken using the FEI Helios NanoLab™ in Tyndall.

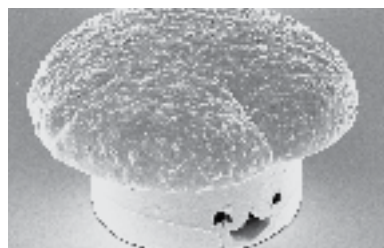


Nano-rose plantation

Pietro Pampili and Vitaly Zubialevich

III-Nitride Materials Group

The lacework surface visible in the area free from nanocolumns is the result of the anisotropic etch rate in the presence of crystalline extended defects.

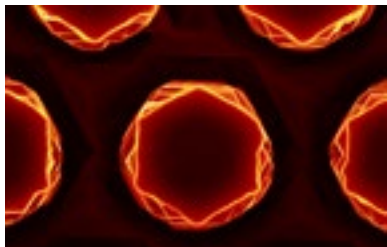


Mushroom man

Daniel Smallwood

Electrochemical Materials and Energy Group

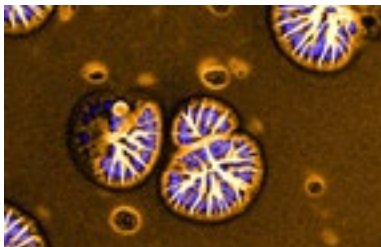
This is an SEM micrograph of an overplated copper pillar on a silicon substrate. An air bubble on the substrate created a plating void, which was filled in by the electroplated copper and magically created the smiling face of a micro-sized mushroom.



Glowing hexagons

Pietro Pampili and Vitaly Zubialevich
Photonics

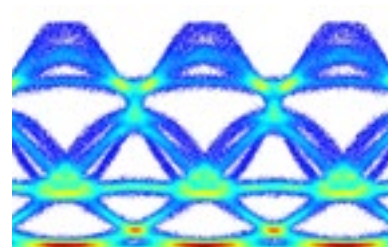
This is a false-colour close-up of GaN nanocolumns after dry and wet etch fabrication steps. The top hexagons were aligned with the m-planes of the wurtzite crystal; the subsequent fabrication steps forced the material to orient along the a-plane directions. As a consequence, a set of 'secondary' hexagons spontaneously formed, all of them rotated by 30° with respect to the top ones.



Jellyfish

Emmanuele Galluccio
Micro and Nano Systems

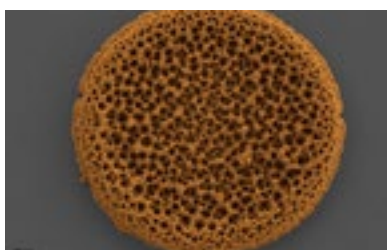
The image is a result of SEM analysis on GeSn coupons subject to ion implantation. In this case, the GeSn layer has been capped with SiN and the cap layer shows degradation due to the dose used in the experiment.



Aliens smile after fibre touring

Xing Ouyang
Photonics

This image comes from a typical 25 Gbit/s on-off keying signal transmission at exactly 25 km of fibre transmission in numerical simulation.



Nano ginger cookie

Vuslat Buk
Life Science Interface

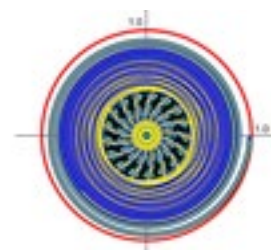
The picture is a result of an electrochemical deposition. This is part of a study for specific applications related to the development of electrochemical biosensors. The study aims to investigate the effect of the different surface modifications on the electroanalytical performance of the desired biosensors.



High five!

Margaret Hegarty
Process and Product Development

A SEM of spray-coated benzocyclobutene (BCB) on plated copper. This was a trial to see if we can passivate the device with spray BCB. The research is developing magnetics on silicon technology.



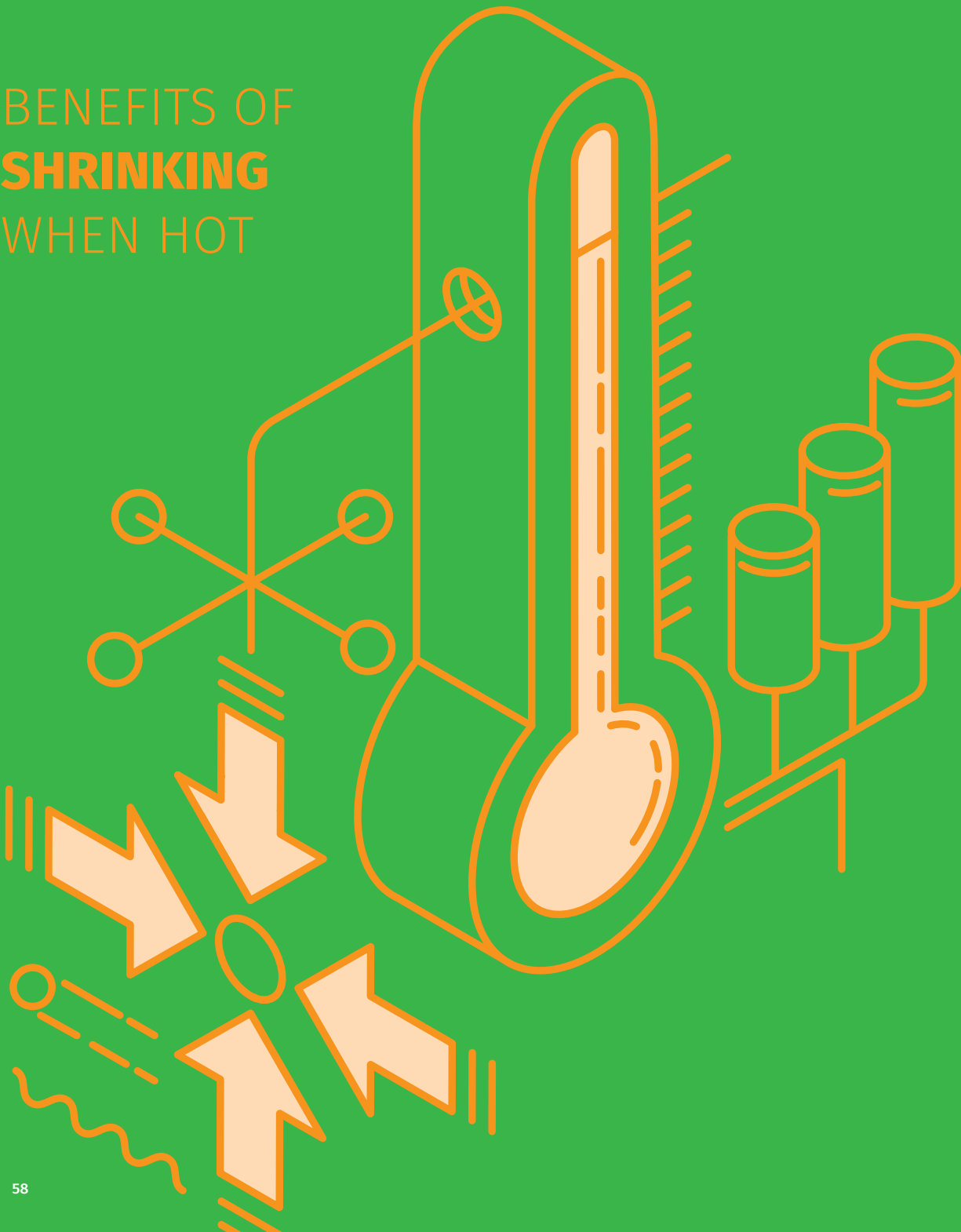
The art of electronics

Ted O'Shea and Liam Floyd
Design Technology Evaluation

A well-manufactured cable has a very uniform spiral, rather than overlapping spirals. This polar plot shows a very high-quality HDMI cable in terms of data transmission integrity with minimal cross-talk.

Financial report

BENEFITS OF
SHRINKING
WHEN HOT



Income and expenditure summary

Income	2018 €000s	2017 €000s
Government grant	4,500	4,500
Research	29,275	29,392
UCC contribution	2,241	2,088
	36,016	35,980

Expenditure	2018 €000s	2017 €000s
Remuneration costs	23,820	23,622
Equipment and infrastructure	1,860	1,617
Consumables and related costs	9,176	8,973
Other operating and deferred costs	1,160	1,768
	36,016	35,980

Board members



Prof. William Scanlon
CEO



Eoin O'Driscoll
Chairman



Prof. Anita Maguire
University College Cork



Marcus Breathnach
Department of Business,
Enterprise and Innovation



Dr Ann Kelleher
Intel Corporation



Ian Quinn



John Mullins
Amarenco Solar



Sean O'Sullivan
SOSV



Jane Williams
Sia Partners



Patricia Reilly
European Commission



Prof. Stephen Ringel
The Ohio State University



Prof. Willy Sansen
KU Leuven



Prof. Richard Penty
University of Cambridge

2018

Highlights

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100+

ACTIVE GLOBAL
INDUSTRY PARTNERS

BENEFITS OF
SHRINKING
WHEN HOT

ELECTROCHEMICAL
BIOSENSORS
MAKING
A REALITY

€36m
OVERALL INCOME

450 PEOPLE
52 NATIONALITIES

CMOS GIVING
TECH
A NEW LIFE



REDUCING
COSTS ON TRANSFER
PRINTING FOR SILICON
PHOTONICS

ON SEMICONDUCTOR
MAPS UP TYNDALL
OSUS SPIN-OUT **sensl**

DRIVING
NEXT-GEN
HEALTHCARE
WEARABLES

270
PEER-REVIEWED
PUBLICATIONS

ROCKLEY
PHOTONICS
LAUNCH R&D
CENTRE AT
TYNDALL

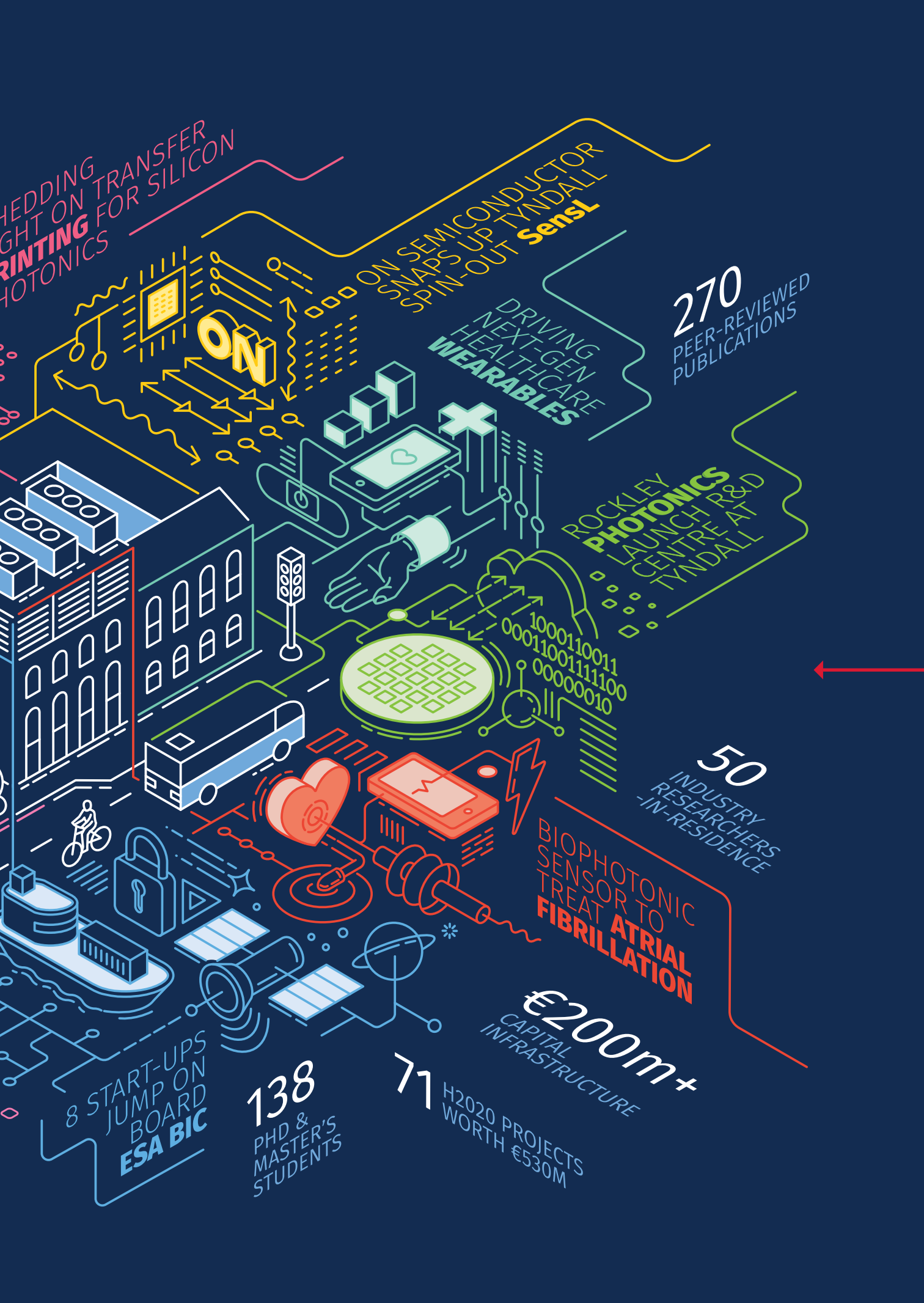
BIOPHOTONIC
SENSOR TO
TREAT **ATRIAL
FIBRILLATION**

€200m+
CAPITAL
INFRASTRUCTURE

138
PHD &
MASTER'S
STUDENTS

71
H2020 PROJECTS
WORTH €530M

8 START-UPS
JUMP ON
BOARD
ESA BIC





Rialtas
na hÉireann
Government
of Ireland

Tionscadal Éireann
Project Ireland
2040



Ireland's European Structural and
Investment Funds Programmes
2014-2020

Co-funded by the Irish Government
and the European Union



European Union
European Regional
Development Fund

A kaleidoscope montage created using a composite of images from our Scientific Image Competition. Images include 'Aliens Smile after Fibre Touring' by Xing Ouyang, 'The Art of Electronics' by Ted O'Shea and Liam Floyd, 'Glowing Hexagons' by Pietro Pampili and Vitaly Zubialevich and 'A Rose is a Rose is a Rose is a Layered Bismuth Telluride Nucleation Seed' by Elaine Carroll.

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