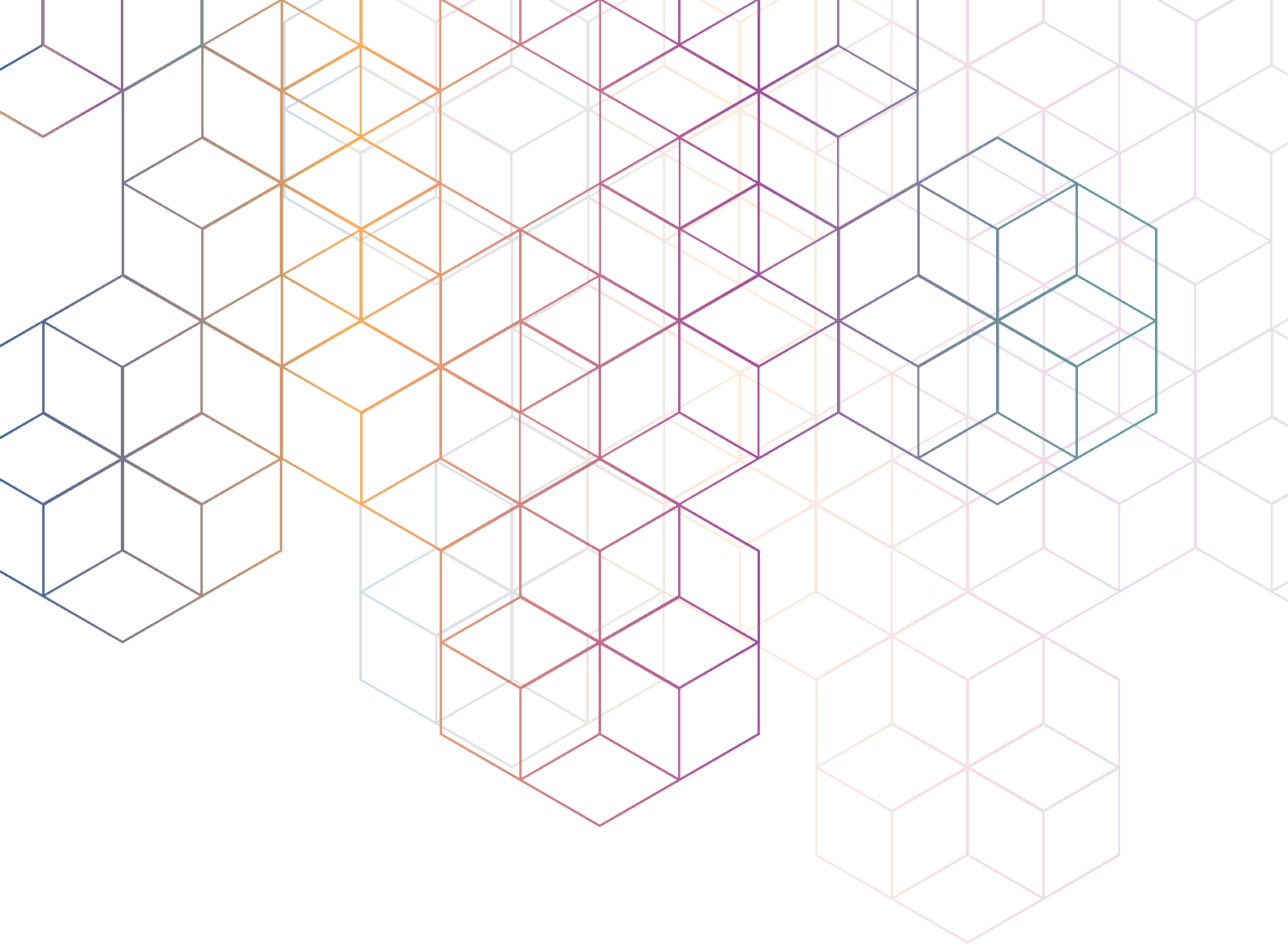
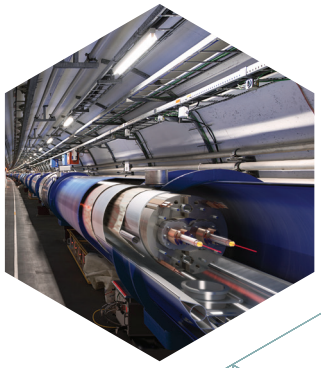
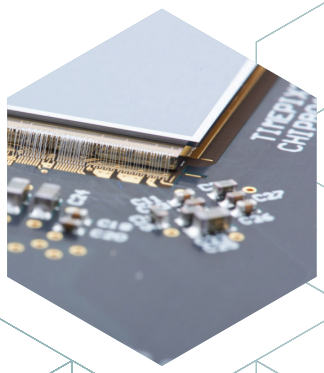


Knowledge Transfer
2016

CONTENTS





“THE RESULTS OF CERN’S RESEARCH HAVE CONTRIBUTED GREATLY TO THE SUM OF HUMAN KNOWLEDGE.”

FABIOLA GIANOTTI, CERN DIRECTOR-GENERAL.

Word from Fabiola Gianotti, CERN Director-General

Curiosity is as old as humankind itself, and it is CERN’s *raison d’être*: this Laboratory is here to explore some of the most compelling questions about the universe we inhabit. Over the years, the results of CERN’s research have contributed greatly to the sum of human knowledge, and the Laboratory has built a reputation as one of the world’s leading centres for fundamental science.

Less well known is the tangible impact we have on everyday lives through the technologies we develop and the skills we nurture. One of CERN’s missions is to maximise the positive impact of these technologies and know-how on society. This is made possible by the CERN community, which represents the human capital that develops the expertise and shares it with society. And this also happens thanks to our engagement with industry and other stakeholders through a variety of different avenues. We also place increasing emphasis on explaining CERN’s societal impact to the scientific community, policy makers, industry and members of the public.

The year 2016 was an excellent one for CERN’s knowledge transfer. In June, I signed an agreement with the Italian National Institute of Nuclear Physics, to establish the ninth Business Incubation Centre (BIC) of CERN Technologies. With these, CERN contributes to building a culture of entrepreneurship. This culture has a concrete impact outside of CERN, and there are currently 18 start-ups and spin-offs using CERN technologies.
In June and November, seven new projects were selected for funding by the CERN Knowledge Transfer Fund, which bridges the gap between research and industry. Since 2011, this initiative has funded 38 projects, with 21 already completed. These projects contribute to many aspects of knowledge transfer, including human capital. They have led to 20 peer-reviewed publications, and eight PhD projects, including six already completed, as well as to the hiring of 17 students or fellows, who went on to work in research or industry.
2016 also saw CERN’s contribution to medical applications significantly strengthened with a more streamlined organisational framework. I believe this will help us work closer with medical communities and Member State countries, with the goal of providing solutions to societal health challenges.

I hope this report will convince you of the vitality of CERN’s activities in this domain and of the new initiatives we have undertaken to transfer our knowledge to those who can use it.

If you are involved with CERN’s research, or work in a relevant industry in science or technology, I hope this report will encourage you to help us ensure that CERN’s knowledge is deployed to the benefit of all.

Above all, I hope this report will leave you inspired by CERN.

Word from Thierry Lagrange, Head of the Industry, Procurement & Knowledge Transfer Department and Giovanni Anelli, Knowledge Transfer Group Leader

Innovation, just like science, works best when it is open. At CERN, Open Innovation has been part of our DNA since its inception. When it comes to knowledge transfer, resources, ideas and technology are shared between our collaborators, from research to industry, with one goal in mind: to benefit society.

This goal to maximise the positive impact of CERN's technology and knowledge on society is directly related to the fact that CERN continues to exist thanks to the policy makers and inhabitants of its Member and Associate Member States. In this sense, it is society that has invested in us, and quite naturally, we are investing back into society.

To make this happen, CERN's dedicated Knowledge Transfer group uses a variety of avenues to accelerate the innovation process, detailed in this report. We see results in the number of start-ups using CERN technologies, the number of industrial partnerships, as well as in the breadth of our application fields highlighted in this report. They include medical and biomedical technologies, aerospace applications, safety, environment, industry 4.0 and many more. None of this would be possible without the expertise and imagination of CERN's engineers, technicians and physicists. CERN is grateful for their daily support to the Organization's knowledge transfer mission.

In 2016, CERN was delighted to be featured as an example of successful innovation initiative in the Global Innovation Index report, co-published by Cornell University, INSEAD and the World Intellectual Property Organisation. We also launched our series of Knowledge Transfer seminars, to showcase the diversity of applications of CERN's knowledge and technology. The popularity of the series exceeded our expectations, and we were thrilled to showcase our activities to CERN members as well as to the general public, who could follow via webcast. The Medical Applications Project Forum (MAPF), where CERN experts can exchange ideas, explore synergies, and catalyse new initiatives, was also launched: this has rapidly become an effective tool to explore the potential of CERN technologies for medical-related applications. We believe the success of these initiatives highlights the curiosity of our stakeholders, and the role of curiosity in the science and innovation process.

2016 was also a year of contemplation, where we reflected on how best to increase the number of companies joining the CERN network of Business Incubation Centres. In 2017, we are looking forward to the challenge of growing this venture further, and building more partnerships with industry.

With this report, we invite all our stakeholders, whether experts in science, technology, industry or policy, to engage with CERN for knowledge transfer opportunities.

FROM CERN TECHNOLOGIES TO SOCIETY

KNOWLEDGE TRANSFER AT CERN

CERN's mission extends beyond science: it also aims to advance the frontiers of technology, to train the next generation of scientists and to bring nations together. The transfer of CERN technologies and know-how to society – grouped under the concept of Knowledge Transfer – is an integral part of each of these activities.

ACTORS OF INNOVATION

Who are the innovation actors that contribute to CERN's successful knowledge transfer? At CERN, a myriad of engineers, technicians and physicists develop new technologies, techniques and models that often have applications beyond their immediate field. CERN stays in close contact with innovation actors from industry – including large companies, SMEs or recent start-ups. CERN benefits from this interaction by gaining an understanding of industry's needs. Industry also benefits by learning about CERN's most recent innovations. Policy makers are also key actors in the innovation process. Their strategic involvement in innovation policy in CERN's member states makes them a key stakeholder for knowledge transfer at CERN.

MEASURING IMPACT

The goal of CERN's Knowledge Transfer activities is impact beyond high-energy physics, by increasing value for all, rather than generating revenue. Addressing global societal challenges, such as health, the environment and contributing to industrial efficiency are examples of positive impact for society.

Measuring impact is an important part of this process. At CERN, we believe one aspect is the breadth of our impact. Our technologies and know-how provide novel solutions in many fields, as illustrated in the infographic opposite. We monitor how our culture of entrepreneurship translates into spin-off and start-up companies (see p42), as well as the bridges we create between science and industry through knowledge transfer agreements, expressions of interest by external parties and internal disclosures (see p25).

BUILDING ON OVER 62 YEARS OF OPEN INNOVATION

Open Innovation is a fundamental paradigm shift: it focuses on creating value from external R&D, relying on both internal and external resources, sharing technology and overcoming the stifling "not invented here" culture. Recent media exposure results from its relatively new adoption by industry, but Open Innovation has been part of CERN's DNA since its inception and is an essential ingredient to its success.

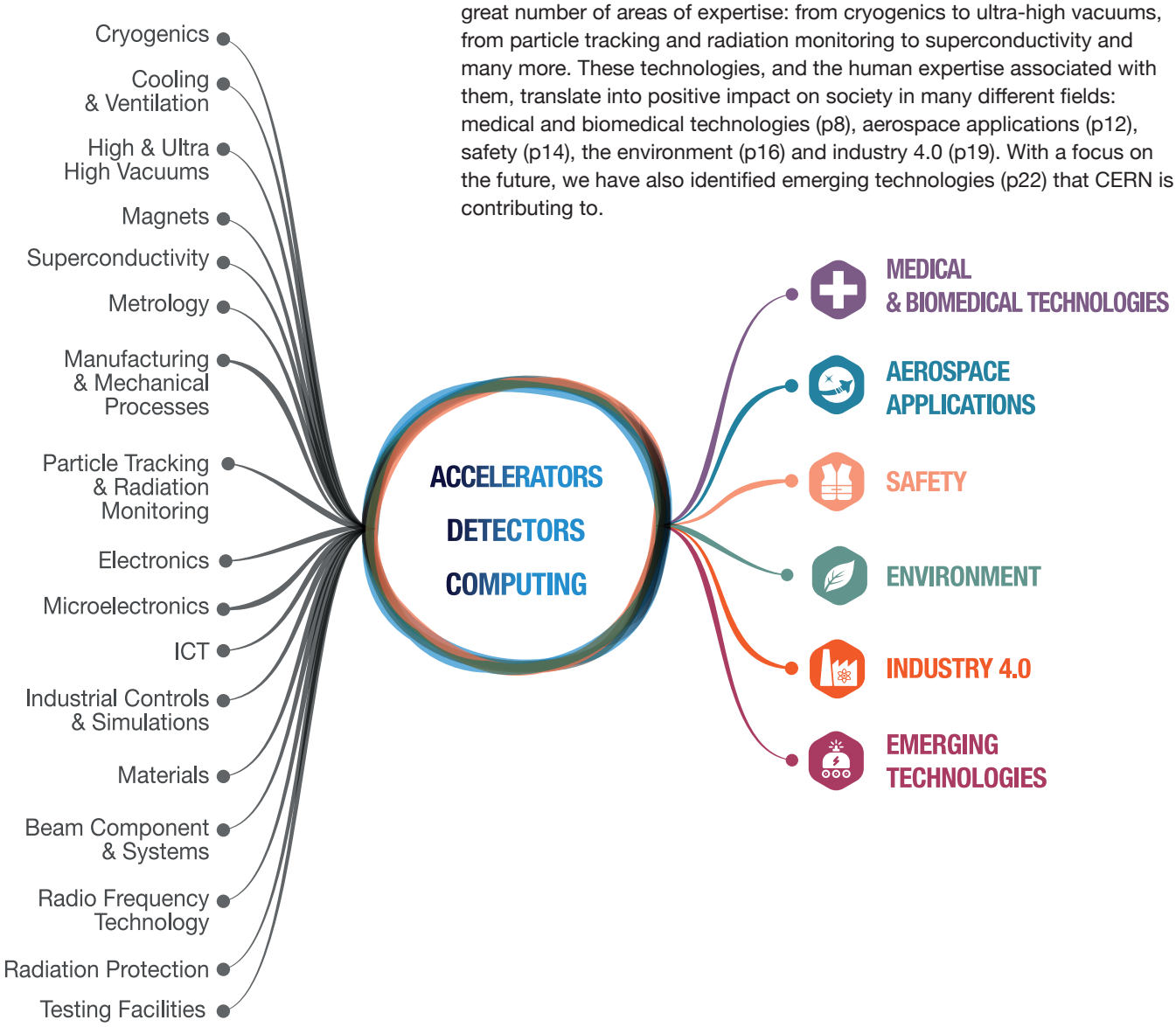
Collaboration is central to CERN: resources, ideas and technology are shared between our collaborators, from research laboratories to industry. Other aspects of our innovation are disruptive, for example, with 24/7 research through the CERN Grid, open access research, as well as our commitment to open source software, and even open source hardware.

Find out more about Open Innovation p24.

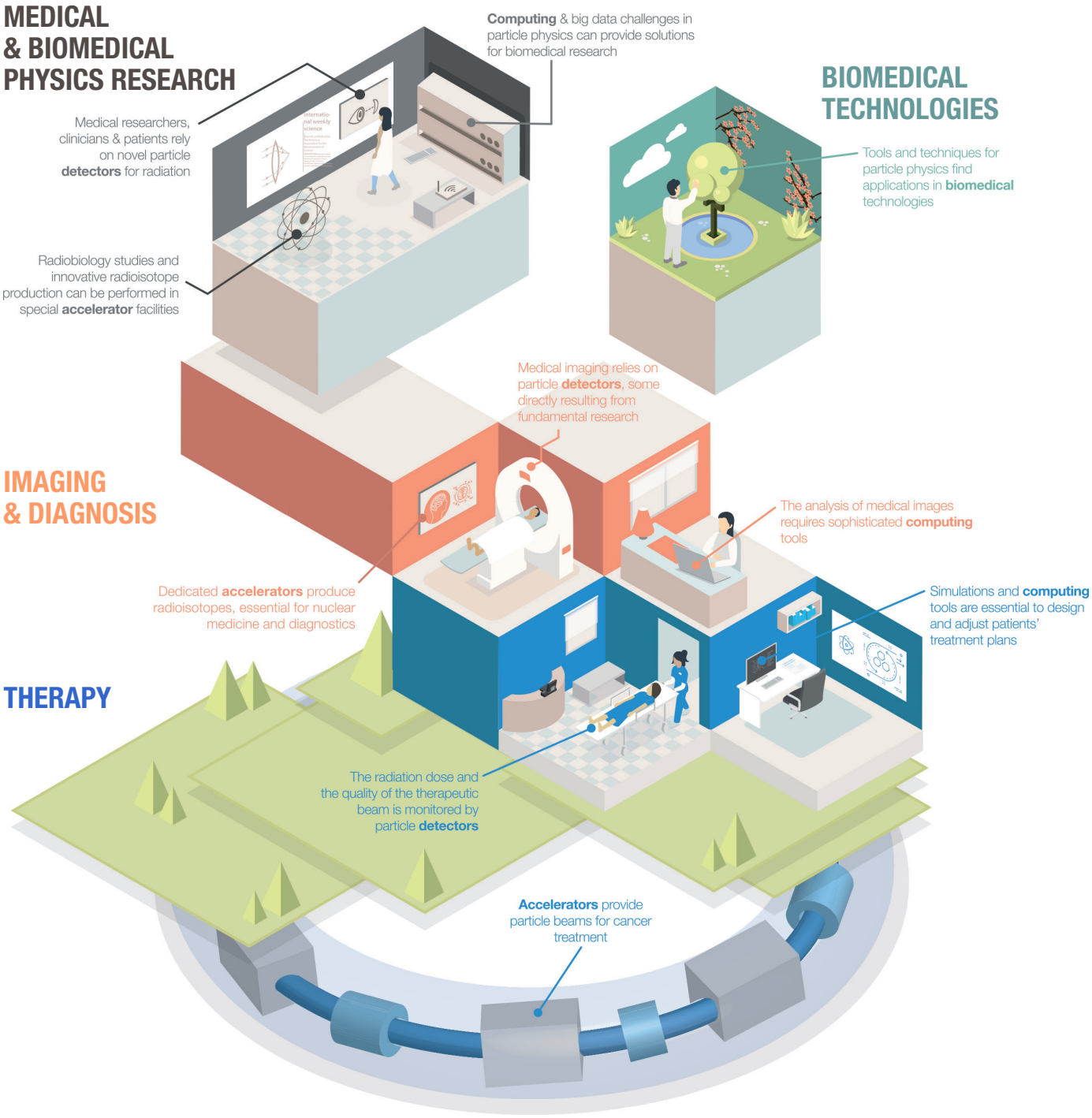
CERN'S SCIENCE ADVANCES THE FRONTIERS OF TECHNOLOGY - THIS BENEFITS SOCIETY.

DIVERSE APPLICATION FIELDS

CERN's expertise builds broadly on three technical fields: accelerators, detectors and computing. Behind these three pillars of technology, lies a great number of areas of expertise: from cryogenics to ultra-high vacuums, from particle tracking and radiation monitoring to superconductivity and many more. These technologies, and the human expertise associated with them, translate into positive impact on society in many different fields: medical and biomedical technologies (p8), aerospace applications (p12), safety (p14), the environment (p16) and industry 4.0 (p19). With a focus on the future, we have also identified emerging technologies (p22) that CERN is contributing to.



MEDICAL AND BIOMEDICAL TECHNOLOGIES



The technologies and scientific advances behind high-energy physics - through developments in accelerators, detectors and computing - have historically contributed to the field of medical and biomedical technologies. Future developments will continue to help address global societal challenges in healthcare, whether for therapy, medical imaging, medical and biomedical research, or biomedical technologies. While fundamental research in particle physics is CERN's core activity, the Laboratory actively contributes to the link between high-energy physics and the medical field.

CERN's aim is to identify its most promising technologies, know-how, services and facilities for future use in the biomedical and medical physics fields, with a focus on those that are unique to CERN.
In 2016, CERN's contribution to medical applications was significantly strengthened through the identification of strategic avenues and the implementation of a more effective organisational set-up. By working closely with medical communities and Member and Associate Member States, CERN can ensure it provides solutions to the end-users' needs.

CNAO: TREATING CANCER WITH IONS SINCE 2011

The National Center for Oncological Hadrontherapy (CNAO) in Pavia, Italy, is a facility offering advanced therapy to fight cancer and one of only five centres in the world treating with both protons and carbon ions. Of the thousand patients treated so far, over 80% exhibit stability. In 2016, CNAO was the first centre in the world to treat eye melanoma patients with the active scanning system where the organ, and – in most cases – visual acuity, were preserved.

Find out more at fondazionecnao.it

MEDAUSTRON: A NEW ION THERAPY CENTRE BECAME OPERATIONAL

MedAustron is a facility located in Wiener Neustadt, Austria, that uses an accelerator to generate ion beams for cancer therapy and research. 2016 has been a busy and exciting year for MedAustron, which has been operating 24/7 since January. In September, the facility qualified to legally operate as an outpatient clinic, and the first medical treatment was performed on 14 December. By 2020, full operation with about one thousand patient treatments will be reached.

Find out more at medaustron.at

CERN-MEDICIS: NOVEL ISOTOPES FOR MEDICAL RESEARCH

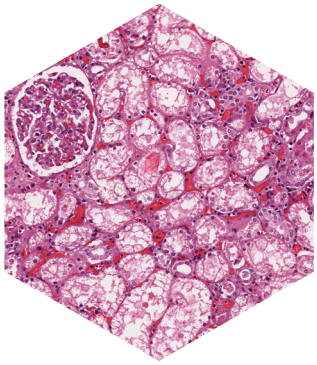
The CERN-MEDICIS facility will produce innovative radioactive isotopes for medical research. In 2016, the installation of the facility has progressed significantly, the MEDICIS collaboration has expanded, and the research activities within the related Marie Skłodowska-Curie Innovative Training Network MEDICIS-ProMED have been showing their first tangible results. 2016 has seen the development of graphene layers on isotope production targets and the first preclinical Terbium-based PET imaging with novel antibodies.
The second Grace-MEDICIS public lecture, on radioisotopes for precision medicine took place on 19 October 2016.

Project Leader: Thierry Stora (Engineering Department – EN)

A MINIATURE LINEAR ACCELERATOR FOR CANCER THERAPY

During 2016 the construction of the 750 MHz Radio-Frequency Quadrupole (RFQ) was successfully completed. This miniature machine is a linear accelerator – or linac; its small size and low current make the RFQ ideal for use in medical and industrial applications. A licence on the RFQ is held by the CERN spin-off ADAM dedicated to the construction and testing of linacs for medical purposes. The RFQ was tuned in record time, and by the end of July it was ready to be moved to the ADAM premises for high-power conditioning and beam tests (see p48).

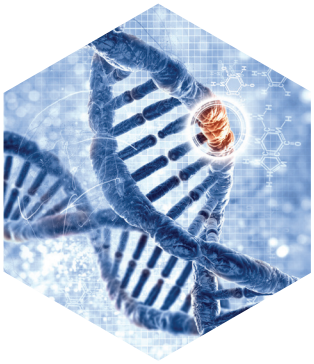
Contacts: Alessandra Lombardi (Beams Department – BE), Serge Mathot (Engineering Department – EN), Maurizio Vretenar (Accelerators & Technology Sector - ATS)



BIODYNAMO: SIMULATING BIOLOGICAL TISSUE DYNAMICS

The BioDynaMo project is part of CERN openlab's collaboration with Intel on code modernisation, and is carried out together with Newcastle University, Innopolis University, and Kazan Federal University. BioDynaMo aims to design and build a cloud-based computing platform for rapid simulation of biological tissue dynamics, such as brain development. Porting from Java to C++ was completed in early 2016 and followed by code optimisation, which will be tested early 2017 and then extended to run in a cloud-computing environment.

Contacts: Alberto Di Meglio and Marco Manca (Information Technologies Department – IT)



GENE ROOT: FROM HIGH-ENERGY PHYSICS TO LARGE GENOMICS DATASETS

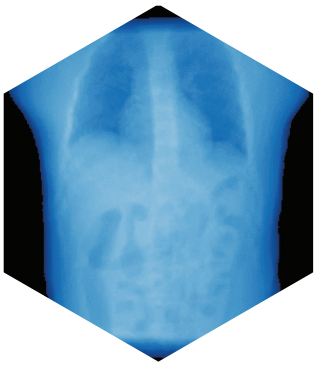
The GeneROOT project, which started in May 2016, is run by CERN openlab in collaboration with King's College London. It aims to use ROOT, a data-processing framework developed at CERN for the high-energy physics community, to analyse large genomics datasets. The project is initially making use of sequences from TwinsUK, the largest UK adult twin registry, but seeks to extend this to similar datasets across the globe. The next step is to integrate the standard data format used in genomics into ROOT and then adapt the analysis tool to the genomics community's needs.

Contacts: Alberto Di Meglio and Marco Manca (Information Technologies Department – IT)

FLUKA: SIMULATIONS FOR HADRON THERAPY

FLUKA is a particle transport and interaction simulation code, originally developed by CERN and INFN for particle physics, which finds applications in a wide range of other domains, including medical. In 2016, FLUKA was used to study the possible advantages of radioactive beams of Carbon 11 or Oxygen 15 for hadron therapy. The nuclear interaction models for light ions (in particular Helium) at energies of relevance for hadron therapy were improved. Assistance was given to external collaborators at CNAO and HIT, in particular for the new features essential for the therapeutic exploitation of Helium beams.

Contact: Alfredo Ferrari (Engineering Department – EN)



TIGRE: A NEW OPEN SOURCE SOFTWARE FOR MEDICAL IMAGING

In 2016, CERN and the University of Bath released a new shareware toolbox for fast, accurate 3D X-ray image reconstruction with applications in medical imaging for cancer diagnosis and treatment. It offers a simple and accessible way to improve imaging and potentially reduce radiation doses for patients. The software is based on Cone Beam Computed Tomography, a scanning process that takes 2D X-ray pictures and processes them into a 3D image. The toolbox is called the Tomographic Iterative GPU-based Reconstruction (TIGRE) Toolbox, and is available open source on GitHub. The collaboration hopes their open source approach will bring together academics and clinicians.

Project Leaders: Manjit Dosanjh (Accelerators and Technology Sector - ATS), Steven Hancock (Beams Department - BE) and Manuchehr Soleimani (University of Bath)

"KNOWLEDGE TRANSFER TO MEDICAL APPLICATIONS IS A GREAT WAY OF FULFILLING OUR MISSION TO DISSEMINATE CERN'S RESULTS TO SOCIETY AS WIDELY AS POSSIBLE." *FRÉDÉRICK BORDRY, CERN'S DIRECTOR FOR ACCELERATORS AND TECHNOLOGY & CHAIR OF THE CERN MEDICAL APPLICATIONS STEERING COMMITTEE.*

"WE DESIGNED AND BUILT THE WORLD'S HIGHEST FREQUENCY, HIGHEST POWER LINEAR ACCELERATOR – AND THIS IS NOW BEING TRANSFERRED TO THE OUTSIDE WORLD."

PAUL COLLIER, HEAD OF THE BEAMS DEPARTMENT.

GEMPIX: A NOVEL DETECTOR FOR DOSE MEASUREMENT IN HADRON THERAPY

In 2016, CERN started investigating the use of GEMPix to measure the 3D energy deposition of a therapeutic ion beam in a water phantom. The GEMPix has been obtained by coupling two CERN-developed technologies, a triple GEM (Gas Electron Multiplier) detector and a Timepix ASIC for readout. The GEMPix has been developed by a CERN/INFN collaboration in the framework of the ARDENT Marie Curie project (2012-2016). The present work includes the development of the necessary software to drive the movement of the GEMPix in a dedicated water phantom, to acquire, normalise and elaborate the data, with the final goal of obtaining real-time imaging of the beam.

Project Leaders: Marco Silari and Johannes Leidner (Occupational Health & Safety and Environmental Protection Unit – HSE), Fabrizio Murtas (INFN Frascati & CERN HSE)

CRYSTAL CLEAR COLLABORATION: SCINTILLATING CRYSTALS FOR MEDICAL IMAGING

Two LHC experiments, CMS and ALICE, use scintillating crystal detectors to measure the energy of photons and electrons produced in high-energy proton and ion collisions. The CERN group of the Crystal Clear Collaboration is developing new fast detector prototypes for use in both high-energy physics experiments and medical imaging, with particular emphasis on Positron Emission Tomography (PET). During 2016, the group was involved in several European projects and two CERN Knowledge Transfer Fund projects for the development of various PET prototypes. A symposium and a public talk were held on 24 November 2016 to mark the 25th anniversary of the collaboration.

Project Leader: Etiennette Auffray-Hillemanns (Experimental Physics – EP)

CERN'S ORGANISATIONAL FRAMEWORK FOR MEDICAL APPLICATIONS ACTIVITIES

CERN Medical Applications Steering Committee (CMASC): prioritises and approves CERN medical applications projects.
International Strategy Committee (ISC): gives input to the CMASC on the needs and priorities of the medical communities.
KT Thematic Forum: brings together CERN and Member States to discuss KT activities, including medical applications.
Medical Application Project Forum (MAPF): gathers all CERN experts in medical applications to identify opportunities and synergies.

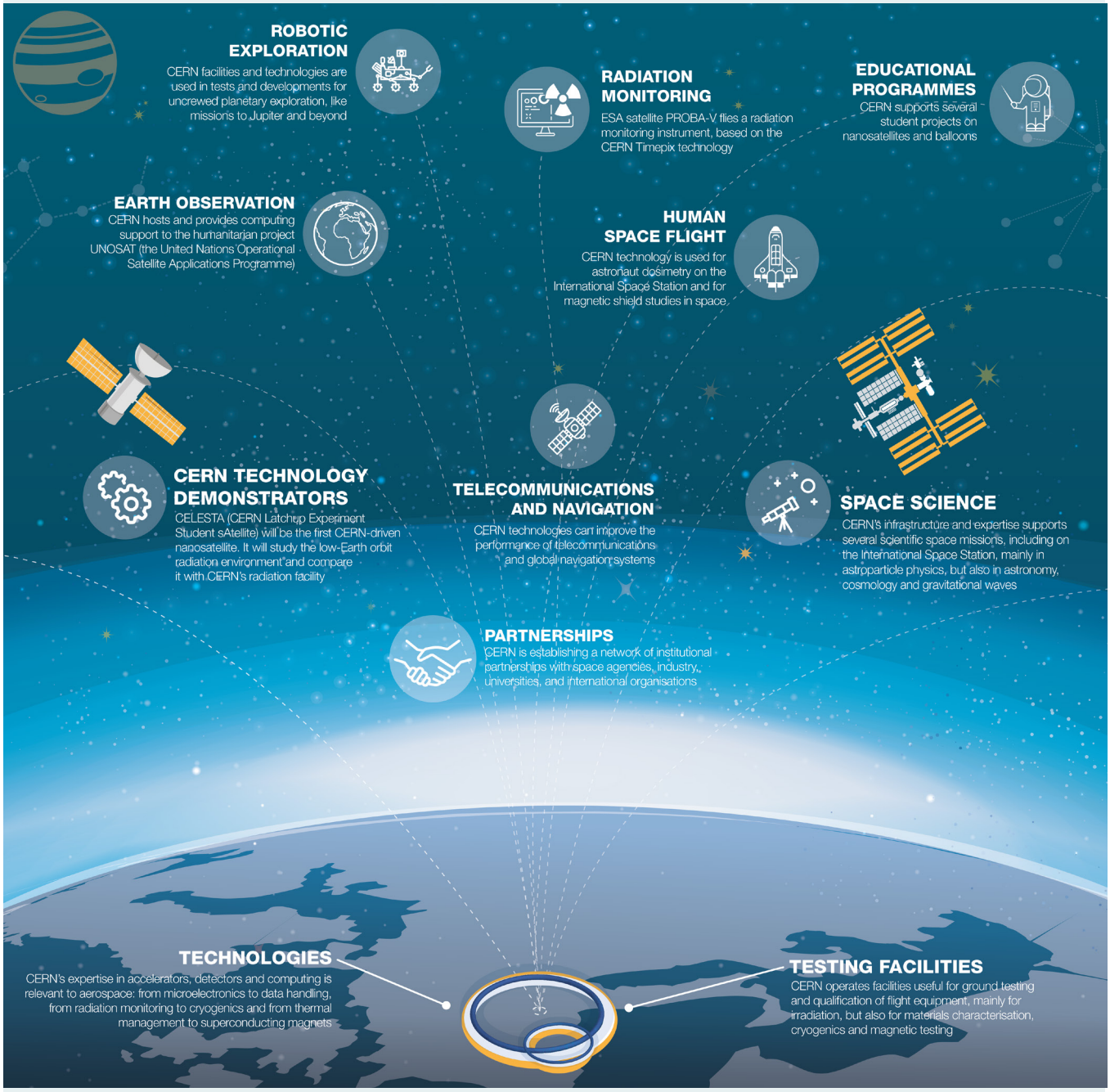
—

The CERN Knowledge Transfer group contributes with its Medical Application section and chairs the MAPF.

AEROSPACE APPLICATIONS

Aerospace is a field in which CERN is playing a critical and increasingly recognised role, based on many natural synergies. Space missions, accelerator and detector infrastructures alike deal with extreme environments, posing stringent technological requirements that often overlap. In this sense, the smallest and largest structures of the Universe have much in common.

To identify collaboration opportunities, CERN is establishing a network of institutional partnerships (see p53) with aerospace organisations world-wide. These allow resource optimisation and can benefit space science missions in astroparticle physics, cosmology and astronomy. They also support technology in-flight demonstrators and projects for: robotic planetary exploration, earth observation, human spaceflight, radiation monitoring, telecommunication and navigation systems and educational programmes.



"WHEN IT COMES TO TECHNOLOGICAL SOLUTIONS, THE SMALLEST AND LARGEST STRUCTURES OF THE UNIVERSE HAVE MUCH IN COMMON."

GIUSEPPE RACCA, PROJECT MANAGER AT THE EUROPEAN SPACE AGENCY

VESPER MAIDEN TEST FOR JUPITER ENVIRONMENT

VESPER stands for Very energetic Electron facility for Space Planetary Exploration missions in harsh Radiative environments. It is a high-energy electron beamline for radiation testing, part of the CTF3 (Compact Linear Collider Test Facility) experimental linear electron accelerator at CERN.
An important application of the beamline is the characterisation of electronic components for operation in a Jovian environment, in which trapped electrons of energies up to several hundred megaelectron Volts (MeV) are present with very large fluxes. In September 2016, in collaboration with the University of Padova, VESPER was used for the first time to test advanced multi-level cell NAND Flash memories, usually used in space.

Project leader: Ruben Garcia Alia (Engineering Department – EN)

CERN VIRTUAL MACHINE FILE SYSTEM FOR EUCLID SCIENCE DATA CENTRES

Sharing software and codes in big data environments is a challenge. To do this efficiently, researchers at CERN have developed a system called CernVM-FS, for CERN Virtual Machine File System, which is currently used in high-energy physics experiments to distribute about 350 million files. The system is also being used for Euclid, a European space mission that aims to study the nature of dark matter and dark energy. The CernVM-FS system has officially been chosen for Euclid software continuous deployment for its nine science data centres.
Since 2016, Euclid is a CERN Recognised Experiment, and the Memorandum of Understanding between CERN and the Euclid Consortium includes the CernVM-FS activities (see p53).

Project leader: Gerardo Ganis (Experimental Physics Department – EP)

CELESTA SUCCESSFUL START OF PHASE B

CELESTA stands for CERN Latchup Experiment Student sAtellite and will be the first CERN-driven microsatellite. Between June and September 2016, it successfully passed its System Requirements Review and has now entered Phase B.
During the review, the technical and programmatic feasibility of the CELESTA concept was validated. The review also highlighted the need to consolidate the payload design through a functional test between the prototype payload cards and the on-board data handling during irradiation. The test was successfully performed mid-October 2016 at the CHARM facility at CERN.

Project leader: Markus Brugger (Engineering Department – EN)

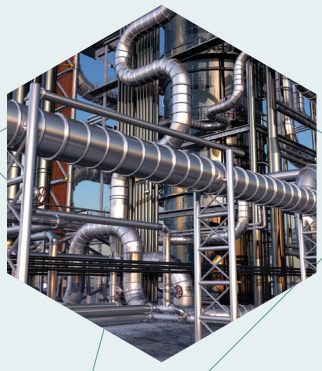
TECHNOLOGIES FOR SAFETY

The safety of people working on the CERN site is of highest priority to the Organization, and CERN's unique environment combining various types of radiation, extremely low temperatures, ultra high magnetic fields and very high voltages, requires innovative solutions for detecting threats and preventing risks from materialising. These technologies are being embraced by some of the leading companies in the field. CERN is proud that its commitment to creating a safe and healthy work environment leads to concrete applications in safety.

B-RAD: ENSURING RADIATION SAFETY IN STRONG MAGNETIC FIELDS

When in the presence of even a relatively weak magnetic field, existing radiation survey meters have difficulties delivering reliable radiation measures. This can be a safety hazard for personnel who rely on radiation measurements to assess threats during interventions. Initially developed for use by CERN's radiation protection group and the fire brigade, CERN's B-RAD portable radiation survey meter uses innovative solutions based on silicon photomultipliers to continue operating in the presence of high magnetic fields. With financial contribution by the CERN Knowledge Transfer Fund, the product has been brought from lab prototype to finalised product in collaboration with the Italian company Else Nuclear. Despite the product still being under finalisation at the end of 2016, the company has already concluded two contracts for sale of units, which it can now produce under a licence granted by CERN.

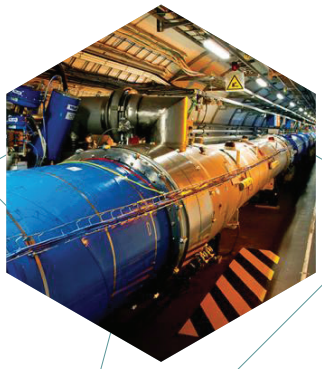
Project leader: Marco Silari (Occupational Health & Safety and Environmental Protection Unit – HSE)



THE COMPACT UNIVERSAL ORBITAL CUTTER: A TOOL FOR INDUSTRIAL PIPING NEEDS

CERN technician Didier Lombard developed a compact new pipe-cutting tool for the Large Hadron Collider, with potential applications in the gas and petrol industry. The tool was developed for inspection and repairs of awkwardly located pipes in tight spaces, and possibly surrounded by radioactive components. Lombard came up with the idea for the Compact Universal Orbital Cutter: an industry-ready tool that can be harnessed to almost any pipe. The revolving compact design enables it to operate in spaces that are otherwise too confined for most cutting machines. The tool answers industrial piping needs in other fields with environmental hazards, such as oil and gas piping, some heat exchangers and piping in nuclear plants. Lombard, who has been a technician at CERN for over twenty years, built a prototype himself. He then applied for the CERN Knowledge Transfer Fund to develop the concept into an industry-ready device, complying with European standards.

Project leader: Didier Lombard (Engineering Department – EN)



KRYOLIZE: NOVEL CRYOGENIC SAFETY SOFTWARE

Kryolize is a software tool for sizing relief valves that protect against overpressure. It is based on international and European standards, and was originally conceived to respond to the specific needs of CERN to develop valves for use with the very low temperature of liquid helium. Kryolize is supported by the Knowledge Transfer group, and benefits from funding from the CERN Knowledge Transfer Fund. Kryolize currently has 30 users at CERN, and six licenses have so far been granted to other research laboratories. Potential applications include domains ranging from the food industry to cryogenic techniques in medicine. Kryolize is also involved in R&D collaborations to ensure that new technologies in the cryogenic field are designed in a safe way.

Project leader: Andre Henriques (Occupational Health & Safety and Environmental Protection Unit – HSE)

Find out more at kt.cern/kryolize-project

LIGHTING YOUR SAFETY PATH IN RADIOACTIVE ENVIRONMENTS

The current generation of emergency lighting, which uses low pressure sodium, is approaching obsolescence. LED technology is predominant for new installations of emergency lighting as it has excellent efficiency and optical characteristics. However, the power supplies currently used are SMPS (switch mode power supplies), which do not withstand radiation. A project to renew the emergency lighting systems within the LHC, and other tunnels of CERN's accelerator complex, has resulted in an innovative design for a radiation resistant power supply.

The main features are: input 220/240V; regulated or unregulated output; available under Open Hardware Licence V1.2; compact design; power efficient.

Project leader: James Devine (Engineering Department – EN)

FLUKA: PARTICLE SIMULATIONS AT YOUR FINGERTIPS

In 2016, there were eleven requests for FLUKA licences. Mainly from companies performing shielding studies, but also some in the field of safety, inspection and auditing that requested the technology, as well as companies working in radio-protection related to dismantling activated industrial facilities. Out of these, two licence agreements were signed and an extension was made to an agreement with a large industrial company which uses FLUKA for a particle therapy centre. One licence was given to a company fingerprinting natural and man-made gemstones using X-ray diffraction techniques, a rather original use of the simulation package.

Project leader: Alfredo Ferrari (Engineering Department – EN)

"AT CERN, WE ARE PROUD THAT THE OUTCOME OF OUR SEARCH FOR INNOVATIONS IN SAFETY IS BEING SHARED WITH INDUSTRY AND WILL ULTIMATELY PROVIDE BENEFITS TO SOCIETY."

SIMON BAIRD, HEAD OF THE HSE UNIT

CONTRIBUTING TO A BETTER PLANET

CERN taps into its technologies and creativity to address another enormous challenge: a healthier and more sustainable planet. CERN's contribution in this area ranges from ultra-efficient solar collectors to novel biochemical sensors for water safety through novel irrigation techniques for the most challenging agricultural environments.

CERN's environmental innovation potential is increasingly acknowledged internationally. This can be seen in CERN's contribution to the 2016 Innovation Week of IRENA, the International Renewable Energy Agency, which highlighted CERN's model of open innovation in its 2016 report. In close collaboration with other European Research Infrastructures (ESA, European XFEL, ESRF, EuroFusion, see p36), CERN held a conference on the opportunities for collaboration on safety and environmental protection at Pollutec 2016, one of Europe's largest industry fairs on green technology, in Lyon, France.

"I AM EXCITED TO BE PART OF A TEAM DEVELOPING TECHNICAL SOLUTIONS TO IMPROVE PARTICLE DETECTORS. THAT THERE ARE WIDER ENVIRONMENTAL APPLICATIONS OUTSIDE THE LAB IS EVEN MORE REWARDING."

MAR CAPEANS, LEADER OF THE DETECTOR TECHNOLOGIES GROUP IN THE EXPERIMENTAL PHYSICS DEPARTMENT

FOSS4 IRRIGATION: HOW CAN HIGH ENERGY PHYSICS HELP WITH WATER SHORTAGE?

Since 2016, CERN is part of a research project to develop a system for optimised irrigation, based on technologies developed for high-energy physics. The irrigation system will use fibre-optic sensors designed to measure parameters such as temperature, humidity, concentration of pesticides, fertilisers and enzymes in the soil of cultivated fields. The system will help build more sustainable agriculture, as it will enable water savings, increased crop yields, and reduced use of pesticides and fertilisers. The fibre humidity sensors are based on those developed for the CMS experiment at CERN's Large Hadron Collider.

The research programme was launched by the UK Lebanon Tech Hub (UKLTH), which is funding the project and coordinating the different participating institutes and companies. CERN, through its commitment to knowledge transfer, will lead the project and provide continued knowledge transfer support after initiating the project.

A key aspect of this project is its open approach: all hardware will be released under CERN's Open Hardware Licence (see p28) and the software will be released under an open source licence within two years of the project termination.

Project Leader: Martin Gastal (Experimental Physics Department - EP)

RADOM: RADON MONITORING FOR CANCER PREVENTION

Did you know that radon – a rare and naturally occurring radioactive gas - is the number one cause of lung cancer in non-smokers? Radon is increasingly becoming a cause of concern for citizens, in particular in areas of higher concentration such as the mountainous regions of France, Switzerland and Norway.

More and more legislation is enacted to reduce indoor radon levels, meaning that measuring indoor radon concentrations rapidly and accurately is becoming an important factor to mitigate radon's health risks.

Building on CERN's long-standing expertise in radiation protection, a very compact radon detector was developed, named RaDoM - for Radon Dose Monitor. RaDoM is unique in its design: a miniaturised pump imitates the human respiratory system, enabling accurate measurement of what is called the "effective long dose", the most accurate indicator of indoor radon health risks to human beings.

The project was selected by the AIDA-2020 Proof-of-Concept fund (see p54) for its innovative nature and for showcasing the positive impact that Europe's detector R&D can have on citizens' every-day lives.

Project Leader: Marco Silari (Occupational Health & Safety and Environmental Protection Unit - HSE)

CAMSTECH: ELECTROCHEMICAL SENSORS FOR WATER POLLUTION MEASUREMENT

It is often said that knowledge transfer is a contact sport – referring to the fact that some of the most surprising collaborations can result from putting the right people together: the passionate scientist and the visionary entrepreneur. The CERN spin-off Camstech Ltd, which joined the STFC-CERN Business Incubation Centre in 2016, is the result of such serendipity after realising that CERN's unique process for making small micrometric holes in printed circuit boards in a predefined pattern was exactly what the company needed for a tiny ultrasensitive biochemical sensor. Although initially aimed at the health sector, the sensor allows for a very accurate measurement of dissolved oxygen in liquids, which is one of the key indicators of water quality. A commercial low-cost version of the sensor will make precise water quality measurement more accessible worldwide.

Find out more at camstech.co.uk

NEUSCHNEE: FROM COMPUTATIONAL FLUID DYNAMICS TO BETTER ARTIFICIAL SNOW

Machine-made snow is now widely used in many ski resorts, but is energy-expensive to produce. CERN's unique expertise from modelling particles in Computational Fluid Dynamics has led to a fruitful collaboration with Austrian start-up Neuschnee, who are specialists in technical snow production.

Producing Neuschnee's "new snow" does not require additives, but is done by mimicking snowflake growth from water particles. This alternative to current snow-making technologies will enable a more natural experience for winter sports and, most importantly, will have a lower environmental impact.

Find out more at neuschnee.co.at

TRACI: AN ENVIRONMENTALLY FRIENDLY COOLER

Cooling CERN's delicate detector electronics also has a strong environmental component: more efficient cooling results in less heat dissipation and energy loss. The choice of coolant is also an important factor on the environmental impact, as traditionally, coolants have been a major cause for air pollution concerns. This is the motivation behind CERN and the Dutch National Institute for Subatomic Physics, NIKHEF's compact CO_2 cooling system. Nicknamed TRACI, for "Transportable Refrigeration Apparatus for CO_2 Investigation", it aims at maximising the cooling efficiency from inexpensive CO_2, which is also environmentally more friendly.

After the production of laboratory prototypes, 2016 saw the birth of the first collaboration to industrialise a compact and transportable version of the system called "MARTA". It is intended to be applied initially in laboratories, though future applications could be as broad as food refrigeration, industrial air conditioning, data centre cooling, and many more. The project relies on the valuable expertise of Cracow University of Technology and industrialisation experience of Polish companies CEBEA Bochnia and PONAR Silesia.

Project Leader: Paolo Petagna (Experimental Physics Department - EP)

INDUSTRY 4.0

Industry 4.0 is a massive trend of increasing automation and efficiency in manufacturing processes with connected sensors and machines, autonomous robots and big data technology. CERN's accelerators, detectors and computing facilities call for the use of the latest industry 4.0 technology, while the technological solutions to CERN's own challenges can be used in the automation industry. Industry 4.0 is topical: in 2016, CERN's Director-General was invited to the World Economic Forum's annual meeting in Davos, whose theme was "mastering the fourth industrial revolution".

ROBOTICS

A TRAIN INSPECTION MONORAIL

TIM, the Train Inspection Monorail, is a mini vehicle autonomously monitoring the 27-km long LHC tunnel and moving along tracks suspended from the tunnel's ceiling. Packed with sensors for visual inspection, infrared imaging and environmental monitoring (oxygen, temperature), the robot can be programmed to perform real-time inspection missions. Thanks to its modular design, TIM can carry additional instruments in one of its wagons, making this an extremely versatile industrial monitoring solution. This innovation has already caught the eye of industry, in particular for autonomous monitoring of utilities infrastructure, like underground water pipelines.

Project leader: Mario Di Castro & Alessandro Masi (Engineering Department - EN)

ROBOTICS SOFTWARE

The CERN Robotics Software is used to manage autonomous movement, which allows a modular robotics platform to perform sophisticated tasks. CERN developed this technology to protect its personnel against hazards in the accelerator facilities. It includes drivers that allow integration of various commercially available sensors and robotic arms into the hardware platform.

The application areas are vast and include inspection, monitoring and remote handling in the hazardous environments of many industries. Its autonomous navigation could help visually impaired people with navigation and even be used in driver assisted cars. The technology is licensed to Ross Robotics, a company that develops modular robotics platforms.

Project leader: Alessandro Masi (Engineering Department – EN)

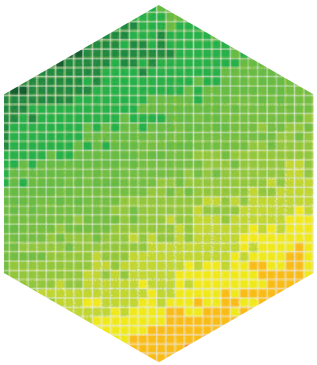
SENSOR TECHNOLOGY ON DRONES

The start-up Terabee uses CERN sensor technology and started off providing aerial inspections and imaging services by deploying drones. After a fruitful collaboration with CERN, where sensors were made to ensure safety of operations in the complex environments of the LHC, the business was expanded to include sensor development. In 2016, the start-up, among others, won the prestigious first place in the automation category of STARTUP WORLD at AUTOMATICA.

Project leader: Alessandro Masi (Engineering Department - EN)

CERN'S ACCELERATORS, DETECTORS AND COMPUTING FACILITIES CALL FOR THE USE OF THE LATEST INDUSTRY 4.0 TECHNOLOGY.

INDUSTRIAL INTERNET OF THINGS



INDUSTRIAL CONTROL AND AUTOMATION

In March, CERN signed a knowledge transfer agreement with the company ETM, (a 100% owned subsidiary of Siemens AG). ETM develops SIMATIC WinCC Open Architecture (WinCC OA), a Supervisory Control and Data Acquisition (SCADA) software that is used in industrial control and automation in a broad range of industries. CERN has used ETM's WinCC OA software for over 15 years and CERN engineers recently developed a software tool to integrate powerful JavaScript visualisation libraries within WinCC OA. This has improved the human-machine interface, enabling a more user-friendly and efficient supervision of the control systems.

The agreement with ETM means the new tool will be deep integrated into future releases of the WinCC OA software and be available to ETM's customers. The exploitation rights related to the agreement will contribute to the CERN Knowledge Transfer Fund.

Project leader: Manuel Gonzalez Berges (Beams Department – BE)

THE QUASAR PROJECT

The Open Platform Communication Unified Architecture (OPC-UA) protocol is a widely used industrial standard for providing software interfaces to hardware devices. The quasar framework is a collaborative, open source effort, for rapid, model-driven development of OPC-UA servers. The project originated from a common requirement amongst CERN development teams to build OPC-UA servers for custom and commercial LHC experiment hardware devices. The framework is also used for other CERN activities as well as externally.

CERN has now entered collaboration agreements with industrial power supply vendors, CAEN and ISEG (and started talks with a third vendor, Wiener), to ensure delivery of integration components for CERN's multi-million CHF installations of their commercial off-the-shelf power supply devices. This is a mutually beneficial agreement: both CERN and the vendors benefit from having high quality standards based integration components to their respective hardware.

The quasar project is distributed under an Open Source licence which facilitates its adoption by a wide community, in both academia and industry.

Project leaders: Benjamin Farnham (Beams Department – BE) & Piotr Nikiel (Experimental Physics Department – EP)

ELECTRONICS FOR EXTREME RELIABILITY AND ACCURACY

PICOSECOND SYNCHRONISATION

At CERN, particles circle the LHC over 11 000 times per second. This means components in the accelerator complex require minute timing accuracy and synchronisation down to 10 picoseconds. White Rabbit is a protocol developed at CERN for monitoring and controlling devices based on industrial networking technology, made available as open hardware and open source software.
In 2016, the technology attracted attention for its applicability in the field of smart electrical grids that have accurate synchronisation needs, where individuals and companies are no longer merely consumers of electricity but also co-creators. White Rabbit is currently being tested on the smart grid of the Milan financial district.

Project leader: Javier Serrano (Beams Department BE)

PROGRAMMABLE DEVICES IN EXTREME CONDITIONS

Programmable devices store configurations and/or the main application code in non-volatile memory. Harsh conditions, such as extreme temperatures or ionising radiation, can corrupt the configuration, leading to a system malfunction.
CERN developed a new multiple memory system (MMS), which solves this problem and increases the reliability of a programmable system located in harsh environments. The new system can identify and bypass a corrupted memory, ensuring continuous access to the information stored. This technology has applications in the field of electronics and was used as an example at the NTNU week (see p42) where positive feedback was received from students and professors.

Project leader: Marek Gasior (Beams Department BE)

POWER CONVERTERS IN EXTREME CONDITIONS

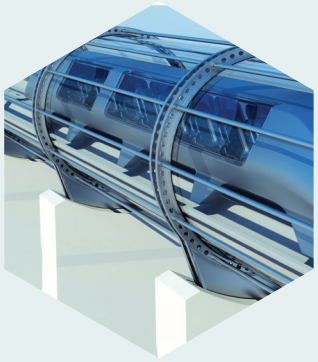
Powering the LHC's magnets requires precise control of the high currents that generate the magnetic field. Power converters transform electrical energy from the electrical grid to the magnets' supply and are highly complex electronic devices, especially those custom-designed for CERN's extreme requirements. These converters have embedded control systems which communicate with other devices over a network. Industry has turned to CERN's expertise to assist with industrialisation of power converters. In 2016, the Italian company OCEM Power Electronics signed a knowledge transfer agreement with CERN to gain valuable expertise in the design of power converters with new markets in sight.

Project leader: Jean-Paul Burnet (Technology Department TE)

EMERGING TECHNOLOGIES

Scientists and engineers at CERN are also working on technologies that are still in the "emerging" phase, and are expected to have significant impact in the future. On one hand, strong interactions between the high-energy physics community and other scientific communities foster the interdisciplinary research necessary for such technologies. On the other hand, CERN's need to plan its research programme in the very long term inspires visionary thinking and advances technology beyond what is considered possible today.

CERN INSPIRES VISIONARY THINKING.



TOWARDS TABLE-TOP SYNCHROTRON LIGHT SOURCES

Synchrotron radiation is a form of high-intensity X-rays, which enables high precision analysis of materials. It is widely used by industry in the fields of pharmaceuticals, semiconductors and even cosmetics. Industry currently turns to large synchrotron facilities for such analyses. However, in countries with no such facilities, it must look abroad, which may be out of reach for some companies. Consequently, a collaboration in the Netherlands, named Smart*Light, has started the development of a table-top Inverse Compton Scattering source for high-intensity X-ray beams. It will enable scientific and industrial applications over a wide range of X-ray energies, such as art analysis and biological soft tissue analysis. CERN's contribution to the consortium is the know-how and expertise in high-gradient X-band accelerator structures.

Technical contact: Steinar Stapnes (Accelerators and Technology Sector – ATS), Walter Wuensch (Beams Department – BE)

HYPERLOOP

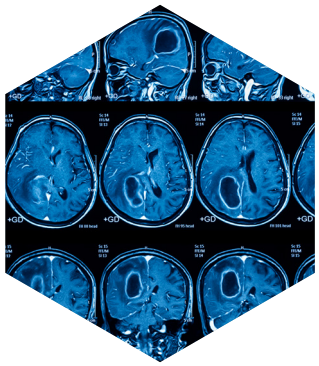
The Hyperloop competition, initiated by SpaceX and Tesla founder Elon Musk, sets the challenge of devising a pod-like transportation system travelling at sonic or even ultrasonic speeds in high-vacuum tubes over several hundreds of kilometres – reducing travel times from hours to minutes. Two CERN Fellows, Marek Gutt-Mostowy and Dario Santandrea, led the Control and Thermal teams of the competition's crowd-sourced and open source participant "rLoop", which received the Pod Innovation award. Also, one of CERN's major industrial partners for ultra-high vacuum technology has now been able to partner with Hyperloop Transportation Technology, thanks to the know-how and experience acquired on the LHC. The possibility of using CERN's innovative CO_2 cooling technology for efficient cooling inside the Hyperloop capsule is currently being explored by "euroLoop" - a new company founded by former rLoop members.

Find out more at hyperloop-one.com

SEMICONDUCTORS FOR MEDICAL IMAGING

G-RAY is a Swiss private company focused on the development and commercialisation of particle detectors and related services for medical imaging. Its collaboration with CERN provides the opportunity to explore the performance of low-temperature bonding processes using established characterisation techniques and expertise relating to microelectronics, microfabrication, microsystems engineering, advanced interconnects, and detector development. The investigation of low-temperature direct bonding of epitaxial Si to CMOS Front-End read-out electronics may provide an interesting solution for the development of monolithic detectors in the field of high-energy physics. Ultimately, this could improve the performance of medical imaging particle detectors.

Technical contact: Luciano Musa (Experimental Physics Department – EP)



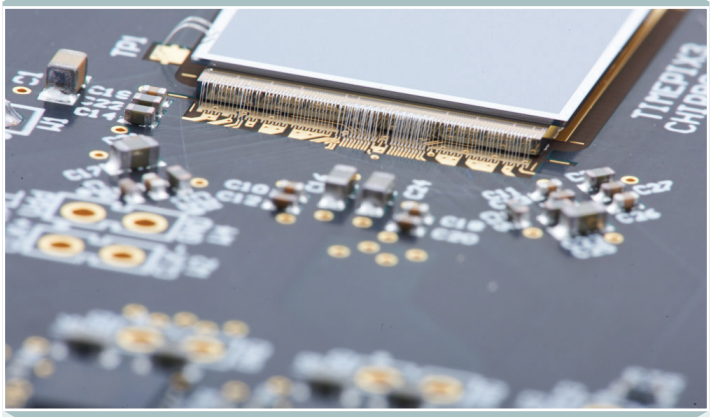
FROM LHC MAGNETS TO HIGH-FIELD MRI AND EFFICIENT POWER GRIDS

The ever-increasing magnetic fields required to achieve the desired energies in colliders like the LHC and in the Future Circular Collider, are the main drivers for developing superconducting cable technology. Two technology synergies are emerging: high-field Magnetic Resonance Imaging (MRI) and “smart” superconducting grids.

An increased magnetic field improves the resolution of MRI, and the collaborative R&D required for new 16 Tesla magnets at CERN has resulted in knowledge transfer towards this new high-field MRI. The collaboration between CERN and CEA (French Alternative Energies and Atomic Energy Commission) has been instrumental in the design of MRI magnets at NeuroSpin, the world’s leading neuroimaging research laboratory.

As 2020 approaches, many countries aim to achieve ambitious climate objectives. Superconductivity is considered to be a key technology for high-efficient energy generation and transport. Superconducting wind turbines could reduce both the weight and ultimately the cost of turbines in large wind farms and for energy transport. Superconductivity is today the only technology which would permit energy transport with nearly no loss over long distances.

Technical contacts: Luca Bottura (Technology Department – TE), Lucio Rossi (Accelerators and Technology Sector – ATS), Amalia Ballarino (Technology Department – TE)



Originally developed for use in the Large Hadron Collider (LHC) experiments, the Medipix technologies have made the journey from CERN to applications across a wide range of sectors - an outstanding example of how technology developed at CERN can create societal impact.

MEDIPIX

The Medipix Collaborations develop hybrid pixel detector readout chips for radiation imaging and other particle detection applications. Since the first Medipix1 chip, providing noise-free, single-photon counting technology, a family of Medipix technologies has emerged. The Medipix2 chip includes improved spatial resolution; Timepix, a modified version of Medipix2, enables time or amplitude measurements; and finally, Medipix3 and Timepix3 extend the functionality by determining the energy level of each individual photon detected.

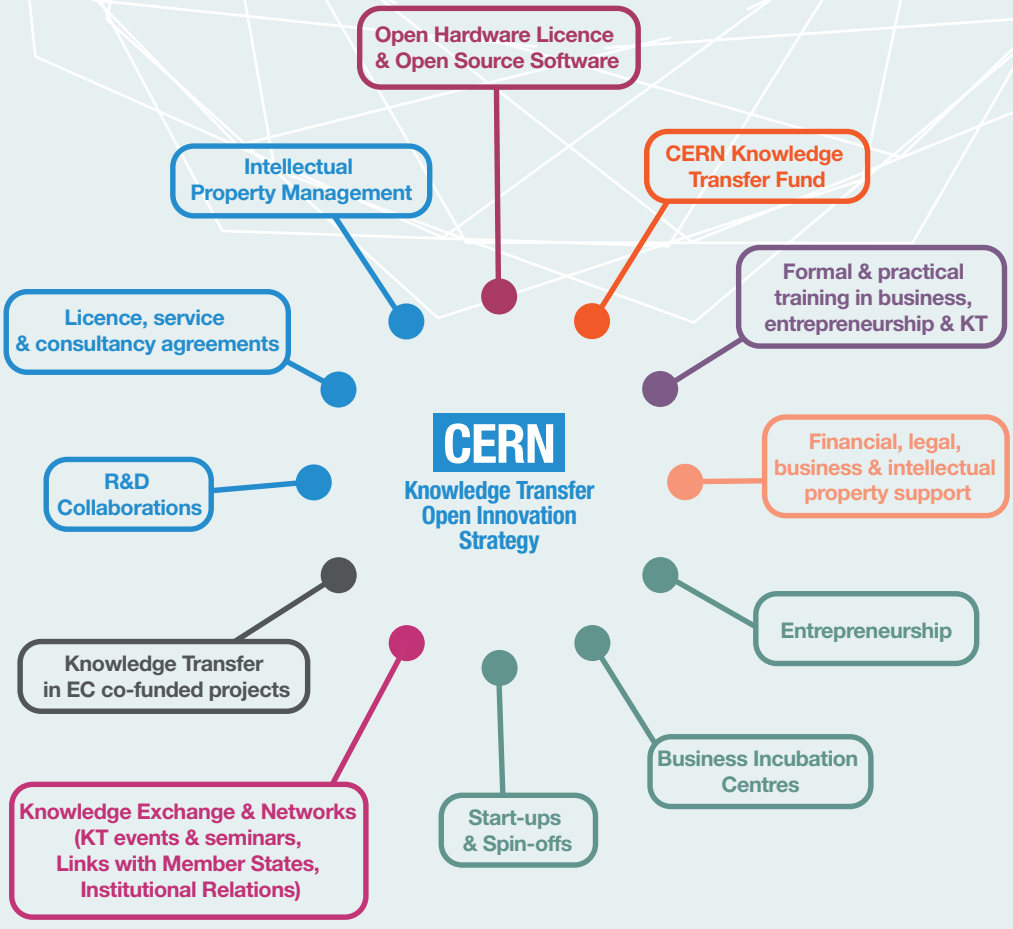
The industrial partners and licence holders commercialising the Medipix technology range from established enterprises to young start-up companies, and from applications within medical imaging to education, space dosimetry, and material analysis. In 2016 the Medipix4 Collaboration was launched, comprised of ten member institutes - again seeking to take this cutting-edge technology to the next level, this time by designing readout chips which can be tiled on four sides seamlessly.

Project leader: Michael Campbell (Experimental Physics Department – EP)

ACCELERATING INNOVATION

KNOWLEDGE TRANSFER TOOLS

Innovation can happen organically, in the sense that new ideas and technologies eventually diffuse into new products or market needs. Actively investing in innovation can accelerate the process. CERN invests in many activities to make this happen, as illustrated in the infographic below. The CERN Knowledge Transfer group provides advice, support, training, networks and infrastructure to ease the transfer of CERN's know-how to industry and eventually society. These activities are all fundamentally based on CERN's Open Innovation strategy, and reach out to CERN personnel, industry, entrepreneurs and research collaborators. This section describes how these activities support the innovation process.



INTELLECTUAL PROPERTY AND LICENSING

Intellectual property (IP) lies at the core of transferring unique CERN knowledge to its industrial and institutional partners. It enables CERN to claim being at the origin of a novel technology and be recognised when products or services based on its unique contributions reach society at large. Intellectual property is not to be equated with patents (see box), which represent only a very small fraction of CERN's knowledge transfer activities.

BREADTH OF INTELLECTUAL PROPERTY

The breadth of IP and how it is used by CERN for dissemination can best be illustrated with the examples below. These highlight the diverse range of IP rights and how their exploitation facilitate CERN's impact on society, in particular in collaboration with industry.

Project	CERN Intellectual Property	Exploitation
Helix Nebula – the Science Cloud	"Helix Nebula" trademark	Ensure proper recognition to the consortium for its contributing members
Medipix family of chips	Detailed chip design and schematics	Licensing to industry in the fields of medicine and X-ray diffractometry
FLUKA	Software code (co-owned with INFN)	Licensing to industry in the fields of safety and patient treatment planning
B-RAD Portable Radiation Survey Meter	Patent (co-owned with Politecnico di Milano)	Licensing to a start-up company that invested R&D efforts into producing a finalised industry-grade product

FROM SCOUTING AND PROMOTION TO CONTRACT

CERN's ownership of IP makes it possible to share its knowledge with industry under mutually agreed conditions by means of a contract. For example, these conditions prohibit use of CERN technology for military applications, a principle which is anchored in the CERN Convention. A mere publication of a technology cannot prohibit such use, but a contract can.

Contracts are the first step to formalise a collaboration to realise innovative products and services by industry for society. They include licences (CERN granting use of its technology under predetermined conditions), service and consultancy (CERN committing to contribute with time and expertise to its contractual partner) or R&D collaborations (CERN and its partner mutually committing time and expertise to a common project).

The path from CERN knowledge to impact requires on one hand a continuous scouting for unique expertise within the Organization, and on the other hand a promotion effort to industry to draw attention to new opportunities for developing innovations for society.

In 2016, CERN's scientists and engineers brought 91 new technologies to the attention of CERN's Knowledge Transfer group. This included a variety of software, electronics, detector and accelerator component designs at various degrees of technology readiness. They ranged from pure idea and lab prototype, which can grow into a mature technology through a mechanism like the CERN Knowledge Transfer Fund, to fully operational solutions.

One single patent was filed in 2016:

Title	Filing date	Application number	Application type	Owner(s)
Method of manufacturing a tape for a continuously transposed conducting cable and cable produced by that method	16 December 2016	EP16204679.1	EP	CERN, Bruker HTS

In 2016, a total of 42 agreements were concluded, described below:

Technology	Type of agreement	Type of partner	Country
MEDIPIX4 Chip	Collaboration Agreement	Academic	FR, DE, NL
MEDIPIX3 Chip	Licence with exclusivity	Company	NZ
MEDIPIX2 Chip	Licence without exclusivity	Company	UK
Hadron Therapy	Addendum to Partnership Agreement	CERN Spin-Off	CH
Hadron Therapy	TT Partnership	Company	AT
Hadron Therapy	Partnership Agreement	CERN Spin-Off	CH
SAMPET Chip	Collaboration Agreement	Academic	FR
	BIC Agreement	Academic	IT
Fibre-optic Sensors	Collaboration Agreement	Academic	IT
Humidity Fibre-optic Sensors	TT Partnership	Academic, Start-up	LB, UK, IT
Sensor Technology for Drones	Addendum 2 to Collaboration Agreement	Start-up	FR
Sensor Technology for Drones	TT Partnership	CERN Spin-Off	FR
fwWebViewPlus Software	Agreement	Company	DE
Microvias by Chemical Etching	Licence without exclusivity	CERN Spin-Off	UK
3D Interferometry	TT Partnership	Academic	CZ
EMPT applied to Niobium	Collaborative R&D	Company	FR
CLIC High-Gradient Accelerating Structures	Collaborative R&D	Company	NL
Scaleable Readout System	R&D Licence	Academic	KR
Scaleable Readout System	Licence	Academic	DE
Quasar Software	2 x Collaborative R&D	Company	DE, IT
Quasar Software	2 x Co-ownership Agreements	Company	DE, IT
High-Frequency Low Energy Compact RFQ	Licence Agreement	CERN Spin-Off	CH
FGC3 Power Converter Controller	Service Agreement	Company	IT
Dual-Modality Approach to Motion-Corrected Tomography	Co-ownership Agreement	Academic	UK
DCCT Calibrator	Service Agreement	Academic	DE
Robotics Control Software	Licence Agreement	CERN Spin-Off	UK
MAD-X and SixTrack Software	TT Partnership	Academic	DE
Integrated CO2 Cooling System	TT Partnership	Academic, Company	PL
Fluka Software	Licence without exclusivity	CERN Spin-Off	UK
NINO-IRPICS Chip	2 x Letter licences	Academic	US
Photonic Crystals	Co-ownership and Exploitation Agreements of Intellectual Property	Academic, Company	FR
Semiconductor Bonding Technology	TT Partnership	SME	CH
Computational Fluid Dynamics	TT Partnership	CERN Spin-Off	DE
ROXIE Software	3 x Letter Licences	Company	UK
ActiWiz Software	Licence without exclusivity	Academic	UK
Solar Collector Technology	TT Partnership	CERN Spin-Off	FR
	TT Partnership	Academic	CH

PATENTS AND OPEN SCIENCE – A CONTRADICTION IN TERMS?

Patents and open science may appear, at first sight, contradictory. Patents, whose role in industry is primarily to prevent competitors from copying a technology, do have a role in facilitating the transfer of knowledge from research to industry. Even where a technology is fully described in publicly available research papers, investing in the further development of the technology by industry may require significant financial resources, often provided by third parties such as seed investors or venture capital (VC) firms. In such circumstances, a licence on a patent, even a non-exclusive one, may mitigate investment risks and therefore result in a technology being transferred where it would otherwise not have been.

It is within that limited scope that open science and patents can comfortably coexist: one serving the dissemination of knowledge, the other as a tool for mitigating the risks associated with the industrialisation of that knowledge. This is also reflected in CERN's patent portfolio, which comprises 49 patents, a number significantly lower than organisations of a similar size where patents serve as a tool for exclusivity agreements or as a metric of innovation.

KNOWLEDGE TRANSFER TRAINING IN 2016

In 2016, CERN continued to provide knowledge transfer training to its personnel, to raise awareness of the support systems in place to transfer their know-how to society. A new course was delivered with the tongue-in-cheek title of "Finding Happiness in Patent Information Databases" on how the wealth of technical information disclosed in patents worldwide can be an added value to colleagues involved in research and development.

IP EXPERT ADVICE WITHIN CERN

To optimise knowledge transfer, CERN relies on the advice of IP law specialists within the Knowledge Transfer group. The group's legal advisors provide support on contractual knowledge transfer matters as well as on general IP issues; primarily helping the knowledge transfer cases at hand with IP, but also providing input into all IP-related topics that may arise within CERN, such as in licensing of CERN material, procurement, or EU-funded projects.

OPEN SOURCE SOFTWARE & HARDWARE

The cornerstone of the "Open Source" philosophy, is that recipients of technology should have access to all its building blocks, such as software code, schematics for electronics, mechanical designs, to study it, modify it, and redistribute it to others. Ever since releasing the WWW software under an open source model in 1994, CERN has continuously been a pioneer in this field: open source hardware (with the CERN Open Hardware Licence), Open Access (with the Sponsoring Consortium for Open Access Publishing in Particle Physics - SCOAP3) and Open Data (Open Data Portal for the LHC experiments).

OPEN SOURCE TECHNOLOGIES FOR OPEN ACCESS

Several CERN technologies are being developed with open access in mind. **Invenio** is an open source software library management package, nowadays benefitting from international contributions from collaborating institutes, typically used for digital libraries. Invenio 3 was launched in 2016, with a whole new concept and full rewrite of the software. CERN, with co-funding from the European Commission, has also long invested in a free Open Data repository, for use beyond the high-energy physics community: **Zenodo.** In September 2016, Zenodo was improved with a new release based on Invenio 3: search became ten times faster, uploads up to 100 GB were also fast, and there were twice as many visitors and three times more records handled. The **CERN Open Data Portal** is also built on Invenio. In collaboration with the Scientific Information Service, 300TB of CMS 2011 data were released. The release received press and media attention and over 210 000 unique site visits.

Project Leaders
Invenio: Lars Nielsen (Information Technologies Department - IT)
Zenodo: Lars Nielsen (Information Technologies Department - IT)
CERN open Data Portal: Tibor Simko (Information Technologies Department - IT) & Sünje Dallmeier-Tiessen (Research and Computing Sector – RCS)

PLATFORM TECHNOLOGIES FOR OPEN COLLABORATION

CERN is also contributing to the development of platform technologies for open collaboration. Over 90% of CERN's compute resources in the data centre are currently provided through a private cloud based on **OpenStack**, that CERN started using in 2012. In 2016, CERN was a major OpenStack contributor, with a CERN member receiving core reviewer status, highlighting the quality of CERN's contribution. The CERN storage system **EOS** was created for the extreme LHC computing requirements. In 2016, EOS instances at CERN approached 1 billion files, matching the exceptional performances of the LHC machine and experiments. EOS (via the CERNBox project) already fully supports disconnected operations as well as file access and sharing via browsers. It is hence now expanding for other data storage needs across CERN, and beyond high-energy physics with AARNET, the Australian Academic and Research Network, and the EU Joint Research Centre for Digital Earth and Reference Data adopting it for their big-data systems. The **Indico** conferencing package is another open source tool developed at CERN, and used by more than 200 sites worldwide, including the United Nations. In 2016, three new Indico versions were released, improving the timetable and category management, and the abstract review process.

Project Leaders
OpenStack : Tim Bell (Information Technologies Department – IT)
EOS: Andreas Peters (Information Technologies Department – IT)
Indico: Pedro Ferreira (Information Technologies Department – IT)

DATA CENTRE ENVIRONMENTAL SENSOR

One of the challenges of long-term digital preservation with tape libraries is contamination by environmental hazards, like dust or any particle that can interfere with the read or write process on tapes. CERN prototyped and built custom dust sensors, based on a Raspberry Pi board and an Arduino processor. In 2016, features were added to the sensor, which can now distinguish between small and large dust particles, as well as detect brief particle emission in high air flows. The updated sensor prevented a major contamination in the CERN data centre in 2016. The use of the sensor is also evaluated at CERN for other use cases: to monitor dust particles in electric racks in the Beams Department, and to monitor dust levels in the CMS pit and cavern.

Project leader: Julien Leduc (Information Technologies Department – IT)

CERN'S OPEN HARDWARE LICENCE IN SOCIETY AND BUSINESS

The CERN Open Hardware Licence itself is a good example of how addressing CERN's needs can have surprising benefits for society. The licence, drafted and published by the CERN Knowledge Transfer group, was born out of the wish to openly disseminate CERN's hardware designs, specifically those related to precision timing and synchronisation across CERN's accelerator complex. The licence fosters the dissemination of schematics and documentation of hardware, and also those related to any improvements made to the hardware. The licence itself is also freely available with the aim of encouraging the availability of open hardware worldwide.

Clearly the licence itself is also addressing a need in other fields, and 2016 saw a variety of surprising and interesting uses, including use in industry.

PLUG-AND-PLAY ELECTRONICS

The New York-based company littleBits sells modular electronic kits for teaching children and adults alike about electronic circuits. By taking away the complexity of electronic circuit design, the plug-and-play system facilitates creative use of electronics. The company, whose products are distributed worldwide and even in some of the major retail stores, has chosen the CERN Open Hardware Licence for disseminating the designs of their modules.

Find out more at littlebits.cc/license

A 3D PRINTABLE 3D PRINTER

3D Printers have created a true revolution in how individuals and small teams can create new products for themselves or for others. Maker spaces, hackathons, student labs and even private individuals now have a tool to make physical objects at very democratic prices with no more than a computer, CAD software and a 3D printer. The Barcelona-based BCN3D company has taken the concept of the 3D printer even further: a 3D printable 3D printer! By making the design, schematics and documentation openly available under the CERN Open Hardware Licence, the company can tap into the know-how and design capability of their users, who are themselves very often electronics engineers.

Find out more at bcn3dtechnologies.com

CLASSIC GUITAR AMPLIFIERS

The CERN OHL is also an enabler for new and innovative business models, wherein the open availability of hardware designs has an incentivising function. A good example of this is how French company A-Wai is crowdfunding the (re-)design of classic guitar amplifiers, which are very popular among a community of enthusiasts. To fund the development of these amplifiers, the company has launched a crowd-funding campaign. The designs of the funded products are made available under CERN's Open Hardware Licence, and the assembled products themselves can be bought from the company or can be built/modified by anyone in the community, in line with the provisions of the licence.

Find out more at blog.a-wai.com

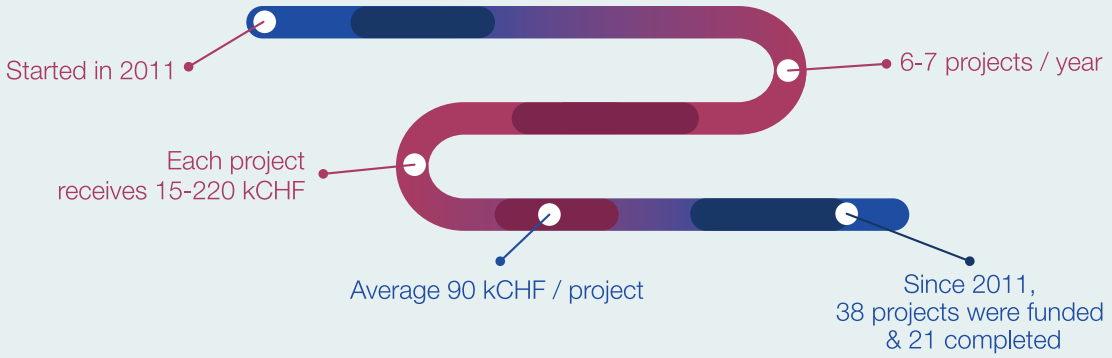
CITIZEN SCIENCE

The CERN OHL is also a driving force in the citizen science movement, as a tool to make affordable scientific instruments accessible to everyone and to foster the improvement of such tools for the benefit of everyone. Notable projects in this field are the UltraScope telescope, designed and made available by the non-profit Open Space Agency, the Cosmic Pi cosmic ray detector developed by a team of scientists who met at THE Port Hackathon or WaterScope, a 3D printable microscope for affordable water testing and discovery for curious young minds.

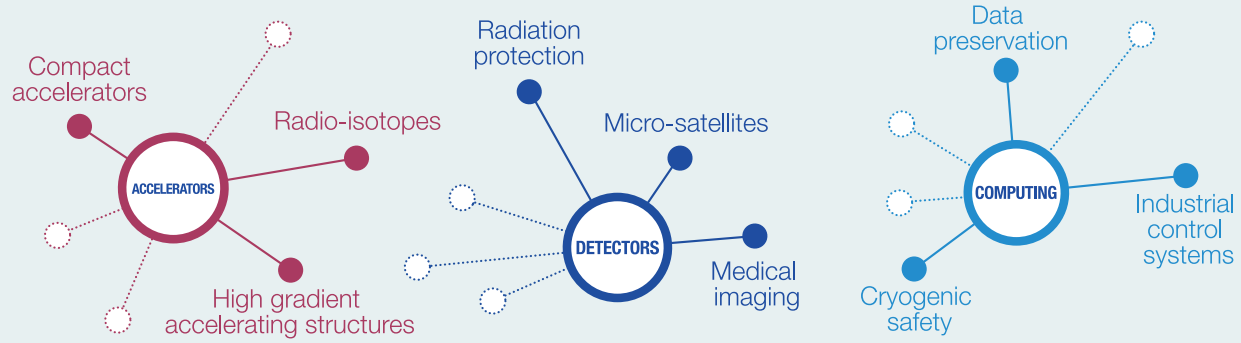
CERN KNOWLEDGE TRANSFER FUND

The CERN Knowledge Transfer Fund bridges the gap between research and industry. Through a competitive process, it selects innovative CERN projects with high potential for positive impact on society. Established in 2011, the fund is supported in part through revenues from commercial agreements concluded by CERN's Knowledge Transfer Group.

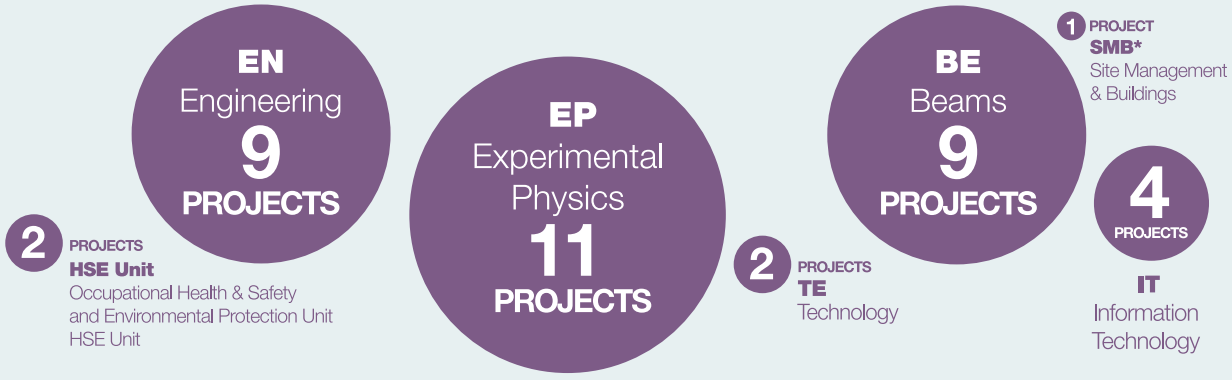
Over the last six years, it has become a pivotal tool to create links between research and industry. This is reflected in the diversity and ambitions of the projects funded; these range from industry 4.0 to data preservation, and from aerospace to medicine. Beyond its mission to champion innovation, it has also contributed to developing human capital. Students and young professionals gained valuable industry-oriented experience. Today, they continue their careers in fundamental or applied research, or industry. Another milestone was reached this year: two EC-funded projects, AIDA-2020 and ARIES, have incorporated a Proof-of-Concept fund modelled on CERN's Knowledge Transfer Fund.



Project Diversity



CERN Departments & Units



* The SMB Department exists since 2016

THE CERN KNOWLEDGE TRANSFER FUND BRIDGES THE GAP BETWEEN RESEARCH AND INDUSTRY, SO THAT SOCIETY CAN BENEFIT.

KNOWLEDGE TRANSFER

17 AGREEMENTS

7 with an industrial partner

10 collaborations with research institutes

INTERNAL SEED FUNDING

306k **CHF** of CERN KT funding was instrumental in obtaining

5 **million euros** in external funding

KNOWLEDGE TRANSFER THROUGH PEOPLE

17 STUDENTS & FELLOWS now working in fundamental / applied research or industry

SCIENTIFIC RESULTS

20 PEER-REVIEWED PUBLICATIONS

6 PhD projects completed

2 in progress

INCENTIVE

internal recognition of SELECTION for a CERN KT grant

INSPIRATION FOR SCALING UP

2 MAJOR EU PROJECTS

AIDA-2020 & ARIES modelled their proof-of-concept fund on the CERN KT Fund

CERN KNOWLEDGE TRANSFER FUND PROJECTS SELECTED IN 2016

THERMAL MANAGEMENT IN HIGH-ENERGY PHYSICS & SPACE APPLICATIONS

High Energy Physics and space applications have similar needs in terms of thermal management for electronic devices. This project aims to develop a miniaturised closed-loop micro-channel cooling device for microelectronics. The result will be efficient cooling devices for a variety of applications, able to handle the increased power density that comes with the miniaturisation of electronics. The project will be supported by the Swiss Space Center and co-funded by Swiss company CSEM.

Project name: Thermal Mangement in HEP and Space Applications (TT-FD-RMS)
150kCHF (+ 150kCHF matched by industry), 2016-2020 (48 months)
Diego Feito & Alessandro Mapelli
(Experimental Physics Department EP)

VERY LARGE SCALE SOFTWARE DISTRIBUTION

Analysing big data requires dedicated algorithms, data structures and computing frameworks. CernVM-FS is a network file system developed at CERN with the help of collaborating institutes and it is critical for the four big LHC experiments. It provides a solution to the challenges of very large scale software distribution. This project will open new avenues for software distribution for very large applications in industry.

Project name: CernVM-FS as a Distribution Engine for Application Containers (TT-FD-DEA)
40kCHF, 2016-2017 (12 months)
Jakob Blomer
(Experimental Physics Department EP)

DISTRIBUTED OPTICAL FIBRE RADIATION & TEMPERATURE SENSOR

Optical fibre radiation and temperature sensors are important to monitor environments with high radiation levels, such as those in the accelerator complex of the LHC. Conventional systems are discretely distributed, but a distributed optical fibre system can provide increased safety and a cost-effective implementation. This project will develop such a system while exploring collaboration with industry and nuclear power facilities.

Project name: Distributed Optical Fibre Radiation & Temperature Sensor (TT-FD-DOF)
150 kCHF, 2016-2019 (36 months)
Diego Di Francesca & Yacine Kadi
(Engineering Department – EN)

LONG-TERM PRESERVATION FOR DIGITAL LIBRARIES

In today's information age, digital archives and digital library projects are crucial to organise, store and retrieve the vast amount of digital content. Invenio is an open source digital library repository system developed at CERN with the help of collaborating institutes. This project aims to plug in a long term preservation layer – the Archivematica SW – to the Invenio software, under the same open source environment and following the OAIS recommendations (ISO stamped).

Project name: Long term preservation of digital content managed by the Invenio Digital Library software. (TT-FD-IDL)
40kCHF, 2016-2017 (12 months)
Jean-Yves Le Meur
(Information Technologies Department – IT)

AUTOMATED FORMAL VERIFICATION OF PLC CODE

Programmable Logic Controllers (PLC) are widely used for industrial automation at CERN as they are also in industry. Reliable functionality of PLCs is crucial, but the released software is currently tested empirically. This project will develop a formal verification framework of PLC code, which will minimise downtime of critical installations and ensure safety.

Project title: Automated formal verification of Programmable Logic Controllers (PLC) code (TT-FD-PLC)
220 kCHF, 2017-2019 (24 months)
Enrique Blanco
(Beams Department – BE)

IMPROVING CRYSTAL DETECTORS FOR PET SCANNERS

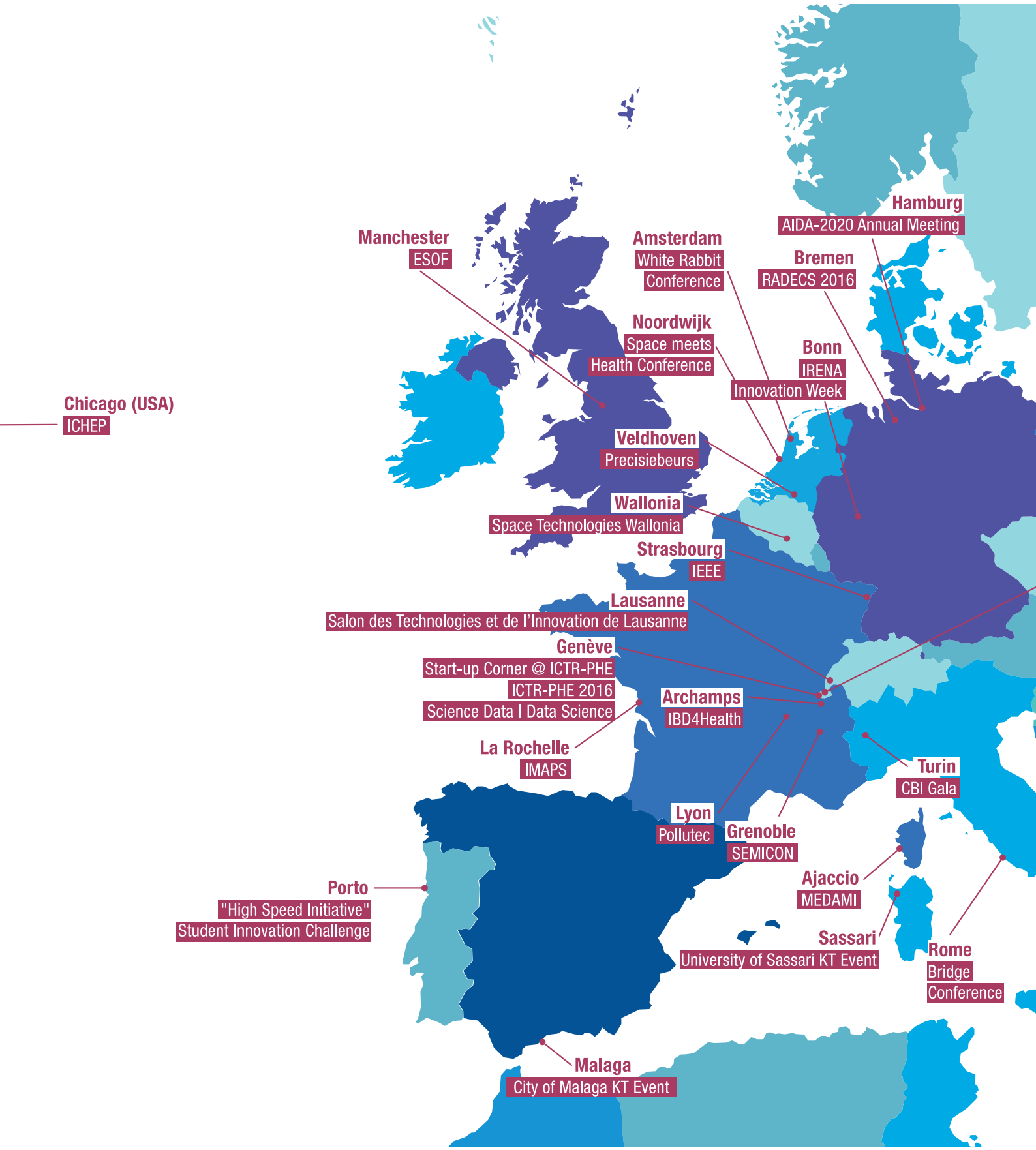
Scintillating crystals are essential for LHC detectors, and have applications in Positron-Emission-Tomography (PET) scanners used for cancer diagnosis and medical imaging in general. This project will enhance the depth of interaction and time resolution of detector modules. This will improve whole-body PET scanning and organ-specific scanning like that required for breast cancer diagnosis. Commercial companies have expressed interest in the concept.

Project title: Development of a detector module with depth of interaction (DOI) capability and with improved time resolution suitable for whole body PET
82kCHF, 2016 -2018 (18 months)
Funded by the CERN Medical Applications budget
Etiennette Auffray-Hillemanns
(Experimental Physics Department EP)

READ-OUT CHIPS FOR HIGH-ENERGY PHYSICS AND MEDICAL TECHNOLOGIES

The NINO ASIC (implemented in 250nm CMOS) is a chip for the read-out of fast radiation detectors (SiPMs, MCPs); it is widely used in high-energy physics and in other fields of science. This project aims to develop a design upgrade in a deeper sub-micron technology (65nm CMOS), by increasing its number of channels, and improving its time resolution. Its specifications arose from the technical requirements of potential users. The chip has potential applications in medical and biomedical fields, e.g. for Time-of-Flight Positron Emission Tomography (PET) or fluorescence detection in biological samples.

Project name: Design of an amplifier/discriminator for radiation detectors with pico-second time resolution
198kCHF, 36 months (2017-2020)
Rafael Ballabriga
(Experimental Physics Department– EP)

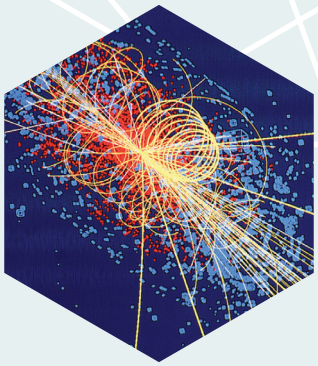

Chicago (USA)
ICHEP
Manchester
ESOF
Amsterdam
White Rabbit
Conference
Hamburg
AIDA-2020 Annual Meeting
Bremen
RADECS 2016
Noordwijk
Space meets
Health Conference
Bonn
IRENA
Innovation Week
Veldhoven
Precisiebeurs
Wallonia
Space Technologies Wallonia
Strasbourg
IEEE
Lausanne
Salon des Technologies et de l'Innovation de Lausanne
Genève
Start-up Corner @ ICTR-PHE
ICTR-PHE 2016
Science Data | Data Science
Archamps
IBD4Health
La Rochelle
IMAPS
Turin
CBI Gala
Lyon
Pollutec
Grenoble
SEMICON
Ajaccio
MEDAMI
Porto
"High Speed Initiative"
Student Innovation Challenge
Sassari
University of Sassari KT Event
Rome
Bridge
Conference
Malaga
City of Malaga KT Event

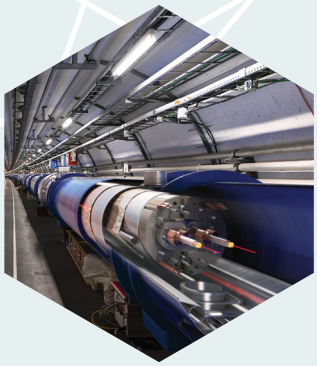
WHERE YOU MET THE CERN KNOWLEDGE TRANSFER GROUP IN 2016

EVENT HIGHLIGHTS

Knowledge Transfer at CERN could not happen without the knowledge exchange between experts in science, technology and industry. Meeting in person is an important step to create and accelerate this exchange. The Knowledge Transfer group organises and presents at key events where these stakeholders are present to do just this. The previous page shows a map of all the events attended or organised by the CERN Knowledge Transfer group in 2016. The highlights of these 2016 events are presented here.

MEETING IN PERSON IS AN IMPORTANT STEP IN CREATING AND ACCELERATING KNOWLEDGE EXCHANGE.





KNOWLEDGE TRANSFER & THE HIGH-ENERGY PHYSICS COMMUNITY

The high-energy physics community is one of the key stakeholders of knowledge transfer activities at CERN. CERN Knowledge Transfer group was present at two of their key conferences. Firstly, at ICHEP, the International Conference on High-Energy Physics, held in 2016 in Chicago. For the first time a parallel session on "Technology Applications and Industrial Opportunities" took place. Secondly at the IEEE NSS/MIC (Nuclear Science Symposium and Medical Imaging Conference) in Strasbourg, France, with an institutional booth managed by the CERN's Knowledge Transfer Group.

Find out more at kt.cern/IEEE2016 & kt.cern/ICHEP2016

KNOWLEDGE TRANSFER & THE CERN COMMUNITY

Knowledge transfer at CERN would not happen without the technology and know-how developed by CERN's community. Various events were organised to engage with these key stakeholders in 2016. The CERN Knowledge Transfer seminars were launched. Along with the CERN Medical Applications Project Forum (MAPF), a series of Early-Career Researchers talks was also launched, highlighting the diverse medical applications that arise from technology developed at CERN. The Experimental Physics "EP-KT Innovation Day", gave researchers an opportunity to showcase recent technological developments.

ESOF 2016

In July 2016, CERN attended the European Science Open Forum (ESOF), as a member of the EIROforum, an umbrella organisation of eight leading European Intergovernmental Research Organisations. The EIROforum's thematic working group on Innovation Management and Knowledge/ Technology Transfer (IMKTT), chaired by CERN, organised a stand showcasing EIROforum technologies which have had a positive impact on society around three themes: Healthcare, Sustainability and Materials. In addition to the stand, there were keynote sessions, panels and events with EIROforum experts.

Find out more at kt.cern/ESOF2016

SEMICON 2016

CERN's knowledge transfer group was at SEMICON 2016, exhibiting its most recent electronics technologies. This was purely an industrial exhibition where the main players in the semiconductor industry were present. Physics technology demonstrators drew the audience to the CERN stand enabling key contacts to be made. CERN presented new applications that have arisen from recent technologies. One notable example was Molybdenum Graphite – a new generation of metal- and ceramic-matrix composites material with useful thermal management properties.

POLLUTEC 2016

EIROforum members CERN, the European Space Agency, the European Synchrotron Radiation Facility and the European X-Ray Free Electron Laser Facility were present at the Green Days of the Pollutec Fair held in Lyon, France, in November 2016. The focus was to showcase their innovations in the domain of energy, environment and risk management, so as to initiate potential collaborations.

Find out more at kt.cern/Pollutec2016

25 YEARS OF CRYSTAL CLEAR

In November 2016, 70 participants attended the celebration of the 25th anniversary of the Crystal Clear collaboration (experiment RD-18). It was established 25 years ago, for the development of new scintillating crystals suitable for the needs of LHC experiments. It has since become a network of excellence, very active and unique in the domain of scintillating materials and their applications, bringing together experts from many disciplines in academia and from the private sector and ready for the challenges of the next generation of detectors.

Find out more at kt.cern/CCC25

ICTR-PHE 2016

The third edition of the ICTR-PHE conference took place in Geneva in February 2016 creating a multidisciplinary platform between physics, biology and medicine with the motto of "going from lab to bed". Over five days, 440 participants from all over the world met and then returned to their home institutes with new ideas, new collaboration prospects and visions for the future for cancer therapy. Young researchers were also given the opportunity to present their work to senior scientists with over 100 of them presenting scientific posters.

Find out more at ictr-phe16.web.cern.ch

RADECS 2016

The annual European conference RADECS - RADiation Effects on Components and Systems organised by Airbus Defence&Space, OHB System and the Fraunhofer Institute took place in Bremen, Germany. It gathered 500 accelerator and aerospace experts from research laboratories and industry, and included a topical day on Jupiter's harsh radiation environment. CERN was represented by the Knowledge Transfer group, the Engineering (EN) and Experimental Physics (EP) departments, at a stand showcasing CERN technologies and facilities. CERN will organise RADECS-17 in October 2017 at the Geneva International Conference Center.

Find out more at radecs2017.com/Radecs2017

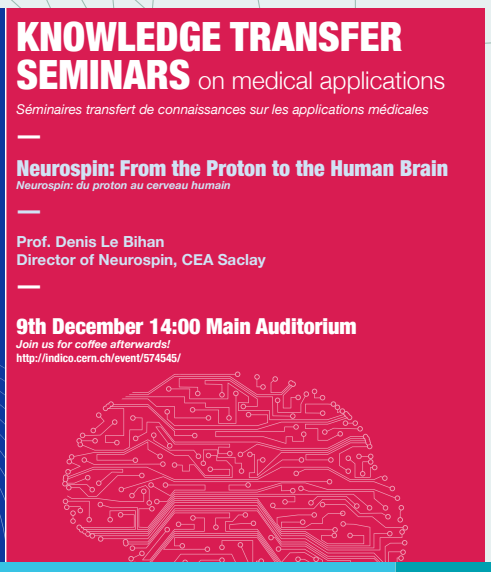
CERN / SWISS SPACE CENTER TECHNOLOGY TRANSFER EVENT

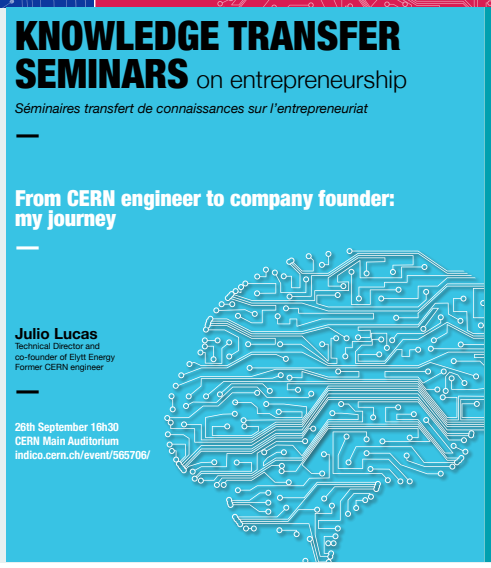
Along with the Swiss Space Center, CERN's Knowledge Transfer group organised a technology transfer event in June 2016 to present relevant technologies and facilities to the Swiss aerospace industry and research groups. Several technologies of potential mutual interest were showcased, including a pilot implementation project related to micro-technology for thermal management of detectors and space systems. Other possible collaborations include the use of CERN's irradiation facilities for space qualification activities.

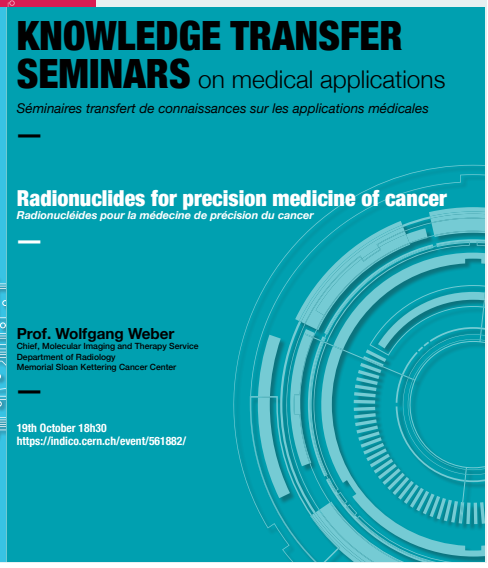
Find out more at kt.cern/SSC2016

CERN KNOWLEDGE TRANSFER SEMINARS

The CERN Knowledge Transfer seminar series was launched in 2016 to showcase the diversity of applications of CERN's knowledge and technology. Speakers from a variety of fields came to CERN throughout the year to explain how applications related to CERN technology or to other high energy physics research activities, can be used in industry, entrepreneurship, medical technologies, aerospace and society. The aim of the seminars is to raise awareness of KT activities, both to the CERN audience and to members of the public who can follow the seminars via webcast.







KNOWLEDGE TRANSFER PARTNERS @ CERN

CERN explores a variety of avenues to engage with experts in science, technology and industry in order to create opportunities for the transfer of CERN's technology and know-how and maximise its positive impact on society. In close collaboration with CERN's dedicated Knowledge Transfer group, IdeaSquare and openlab explore how research and industry can collaborate in the innovation process.

IDEASQUARE

Continuing to work in very close partnership with the CERN Knowledge Transfer group, IdeaSquare provides a test-bed for new ideas and concepts that may have an impact on society, inspired by the unique scientific and collaborative atmosphere at CERN. During its second year of operation, IdeaSquare continues to make important progress in connecting detector-related R&D activities with cross-disciplinary MSc-level student teams working on societal challenges. The purpose of IdeaSquare is to demonstrate the concrete use of basic research for society, and act as a demonstrator for the ATTRACT initiative. During 2016, IdeaSquare organised or hosted over 80 events. These included workshops run by the CERN Knowledge Transfer group for students and external instances; Challenge Based Innovation courses, and weekend hackathons such as The Port, Internet of Things, Open Science and building 3D printers. IdeaSquare currently hosts seven detector R&D related projects. An online journal has been created to record the education and innovation related processes at IdeaSquare to measure longer-term societal impact.

Find out more at cern.ch/Ideasquare

CERN EXPLORES A VARIETY OF AVENUES TO ENGAGE WITH EXPERTS IN SCIENCE, TECHNOLOGY AND INDUSTRY.

OPENLAB

CERN openlab is a unique public-private partnership through which CERN collaborates with leading Information and Communications Technology (ICT) companies and research institutes. The primary goal of the collaboration is to accelerate the development of the cutting-edge ICT technologies that support CERN's ground-breaking physics research.Throughout 2016, work was carried out to tackle ambitious challenges covering the most critical needs of ICT infrastructures. This included activities in domains such as data acquisition, computing platforms, data storage architectures, compute provisioning and management, networks and communication, and data analytics.

2016 marked 15 years of CERN openlab's work in support of the LHC research community. This anniversary was celebrated at the CERN openlab 'open day' event.

2016 also saw the conclusion of ICE-DIP, the Intel-CERN European Doctorate Industrial Programme, a Marie Curie Actions project part of FP7.

The CERN openlab Summer Student Programme continued to go from strength to strength in 2016, with CERN openlab also sponsoring the CERN Summer Student Webfest for the first time.

Work has now begun to identify the ICT challenges that will be tackled in CERN openlab's sixth phase, which will run from 2018 to 2020.

CERN openlab is collaborating with the following companies and research institutions:

Partners: Intel, Oracle, Siemens.

Contributors: Brocade, Cisco, IDT, Rackspace, Seagate.

Associates: Comtrade, Huawei, Yandex.

Research members: The European Bioinformatics Institute (EMBL-EBI), GSI Helmholtzzentrum für Schwerionenforschung, Innopolis University, The Italian National Institute for Nuclear Physics (INFN), Kazan Federal University, King's College London, Newcastle University.

Find out more at openlab.cern

STRENGTHENING LINKS WITH MEMBER STATES

CERN is run by 22 Member States and 6 Associate Member States, and its success is in large part due to this rich international collaboration. To accelerate industry links and create new opportunities with its member states, CERN actively engages with them. This happens through its dedicated KT Forum, through national industry days, like France@CERN or Holland@CERN in 2016, or by participating in events in its various member states.

THE *KT FORUM*

The *KT Forum* brings together CERN's Knowledge Transfer group and Knowledge Transfer representatives from CERN Member and Associate Member States. The forum is a platform to discuss CERN's knowledge transfer activities and to help liaise with industry in CERN member states. The new technologies are developed at CERN, and are either immediately available for dissemination or are suitable for R&D contracts with national industry, which help the technology become market-ready. The KT Forum met twice in 2016. The March meeting focussed on the presentation of CERN's 2015 Knowledge Transfer Annual Report, presenting relevant knowledge transfer activities and new technology opportunities. The September meeting was mainly dedicated to Medical Applications and the new structure for these activities, which was implemented in 2016.

FRANCE AND HOLLAND @CERN

Every year, CERN Member States can chose to hold industry days at CERN. During these, they can present potential suppliers that CERN could use for its procurement needs. Such events also present a great opportunity for synergies between procurement and knowledge transfer, two sides of industry partnerships with CERN. Participating companies can request information about new technologies available for transfer. In May 2016, Holland@CERN took place, gathering 33 innovative companies from the Netherlands. In October 2016, it was France's turn with an impressive exhibition of 37 companies represented.

PRESENCE AT KNOWLEDGE TRANSFER EVENTS IN MEMBER STATES

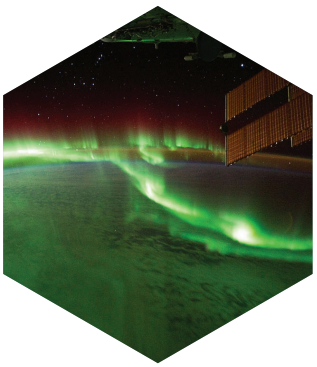
To liaise more effectively with industry, the CERN Knowledge Transfer group often participates in events organised in its member states. These are good opportunities to engage with local communities and companies, and they allow discussion with several companies simultaneously.

CERN 2016 presence at Knowledge Transfer Events in Member and Associate Member States:

- 25-26 January, Switzerland meets Wallonia in Space Technologies
- 23-24 May, KT Event in Italy, hosted by the University of Sassari
- 30-31 May, KT Summit in Turkey, hosted by the Istanbul Bilgi University
- 26 September, Event to present the Spanish BIC, hosted by the city of Malaga
- 16 November, Precision fair, The Netherlands

CERN Member States:
Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Israel, Italy, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Spain, Sweden, Switzerland, United Kingdom

CERN Associate Member States:
Cyprus, India, Pakistan, Serbia, Turkey, Ukraine



SWITZERLAND MEETS WALLONIA IN SPACE TECHNOLOGIES

CERN was invited to “Switzerland meets Wallonia in Space Technologies”, organised by AWEX/WBI (Walloon Export and Foreign Investment Agency and Wallonie-Bruxelles International), with Skywin (Aerospace cluster of Wallonia) and SSC/SERI (Swiss Space Center and Swiss State Secretariat for Education, Research and Innovation). The Swiss delegation met Wallonia-based aerospace companies, visited the Liège Space Center and discussed joint innovation opportunities within the EUREKA and Eurostars frameworks.

KNOWLEDGE TRANSFER EVENT IN ITALY

INFN and CERN participated in a knowledge transfer event organised by the University of Sassari (Italy) in May 2016. The two institutions presented their technology transfer activities to a large audience of academics and companies, focussing in particular on the cultural heritage activities of INFN and CERN’s aerospace applications. The event was also an opportunity to visit the local business incubator CubAct, a candidate to join the Italian network of BICs of CERN Technologies.

CERN AND TURKEY TRANSFER KNOWLEDGE

CERN and Turkey held a joint knowledge transfer summit in Istanbul on 30–31 May 2016, aimed at strengthening links between science, technology and industry. The summit, held at Istanbul Bilgi University, brought together leaders from academia and industry, including the CERN Knowledge Transfer Group, Turkish technology-transfer offices and industrialists. Around 100 participants from more than 35 university technology-transfer offices, 20 companies and several state institutions attended.

SPANISH BIC PRESENTATION IN MALAGA

On the 26 September 2016 CERN participated in an event organised by the City of Malaga (Spain) to present the Ineustar-Pioneers Network of BICs of CERN Technologies in Spain, with Promalaga being the first BIC joining the network. The event, opened by the Mayor of Malaga, was an opportunity to present the opportunity to potentially interested partners from the region.

PRECISIEBEURS

In 2016, CERN, as part of the Big Science collaboration, participated in Precisiebeurs - the Precision Fair - Europe’s largest fair for precision manufacturing and precision-related industries. The KT representative contributed with a presentation on how knowledge and technology transfer is done at CERN and what opportunities there are for industry, aside from procurement projects, generating interest and leading to follow-up discussions.

ENTREPRENEURSHIP

BUILDING A CULTURE OF ENTREPRENEURSHIP

Entrepreneurship at CERN is all about building bridges: between engineers and financers, between physicists and marketers, and more generally between science and business. In 2016, CERN continued to work towards building several such bridges to create a general culture of entrepreneurship within the Organization. The many avenues explored include our network of Business Incubation Centres, Entrepreneurship Meet-Ups and Mixers and many more.

"CREATIVITY AND INNOVATION FLOURISH WHEN PEOPLE COME TOGETHER AND SHARE IDEAS."

SPERANZA FALCIANO, VICE PRESIDENT OF INFN.

BUSINESS INCUBATION CENTRES

A network of nine Business Incubation Centres (BICs) aims to assist entrepreneurs and small technology businesses with taking CERN technologies and expertise to the market. The BICs support the development and exploitation of innovative ideas related to CERN technologies in the fields of accelerators, detectors, and computing.

Find out more on p44 or at kt.cern/bic-network

START-UPS & SPIN-OFFS

There are currently 18 start-ups and spin-offs using CERN technology and know-how. In December 2016, CERN was invited to one of Europe's biggest start-up conferences, Slush. As part of the Slush Science Track, CERN gave a keynote speech on how start-ups and fundamental research are both dependent on innovation.

Find out more on p46 or at kt.cern/startup

ENTREPRENEURSHIP MEET-UPS

The Knowledge Transfer group launched the CERN Entrepreneurship Meet-Ups (EM-Us) in 2014 to foster entrepreneurship within the CERN community. CERN and external experts are invited to present their expertise; the talks are followed by discussions and are an opportunity for networking. Topics in 2016 included negotiation, entrepreneurial ecosystems and start-up selling.

Find out more at kt.cern/meet-up

ENTREPRENEUR MIXER & GLOBAL ENTREPRENEURSHIP WEEK

An *Entrepreneur Mixer* was organised in June 2016. Four start-up companies with ties to CERN pitched their concepts to people from both inside and outside of CERN. The aim was to show the outside world how CERN know-how and technology can be applied in society, and show the CERN community that their skill sets are attractive to start-up companies. A few months later, a similar networking event was set up as a part of the *Global Entrepreneurship Week Geneva*, bringing people from several different industries to CERN.

CERN-NTNU SCREENING WEEK

In October, 40 students from the Norwegian University of Science and Technology (NTNU) spent a week at CERN to evaluate the business potential of four different CERN technologies: the narrow diffractive beam (NDB) generator; high pressure laminates; multi-memory management system; and compact, light, fast-trimmable magnets. At the end of their stay they delivered reports with their findings.

SOCIAL ENTREPRENEURSHIP – THE PORT

THE Port humanitarian hackathon 2016 was hosted at CERN with 60 participants from 30 countries. Participants were grouped into eight multidisciplinary teams balanced with a mix of professions, ages, nationalities, and genders to tackle eight humanitarian challenges. Teams from previous hackathons have successfully developed their prototypes after the event. The 2014 Better Body Bags team got selected among the TOP25 startups in Switzerland, and produced 100 body bags that are currently delivered to the International Committee of the Red Cross under an R&D contract. They have also won a grant to produce another ten thousand. Also from 2014 the topic of building a low cost inflatable fridge for field operations led to a brand new startup, Ideabatic, which was recently awarded a £25k prize by ViiV Healthcare.

CHALLENGE BASED INNOVATION

Challenge Based Innovation (CBI) is a project course where multidisciplinary student teams and their instructors collaborate with researchers at CERN to discover novel solutions for the future of humankind. The projects are an elaborate mixture, where the technologies derived from research at CERN meet societal, human-driven needs. CBI @ mediterranean ran from 12 September to 2 December 2016, culminating in a prototype expo held at CERN introducing the student teams' results. Another project, Innovation for Change, rewarded the business ideas developed by 50 MBA students from Scuola di Alta Formazione al Management (SAFM) and graduate students from Torino Polytechnic in Italy. The students' prototypes were evaluated by a jury that included the CERN Director-General.

Find out more at cbi-course.com

START-UP CORNER AT THE ICTR-PHE 2016 INDUSTRIAL EXHIBITION

The 2016 International Conference on Translational Research in Radio-Oncology | Physics for Health (ICTR-PHE) welcomed 16 exhibitors and sponsors at its industrial exhibition, including major particle therapy companies. A dedicated start-up corner gave six start-ups from the Netherlands, Italy, and France an opportunity to showcase and pitch their companies. The startups' sectors ranged from Monte Carlo simulation for radiobiology to real-time exchange, and from collaboration in clinical trials to e-learning for training in radiotherapy. The start-up corner raised awareness of the young companies, and showcased how entrepreneurship can fit in with research.

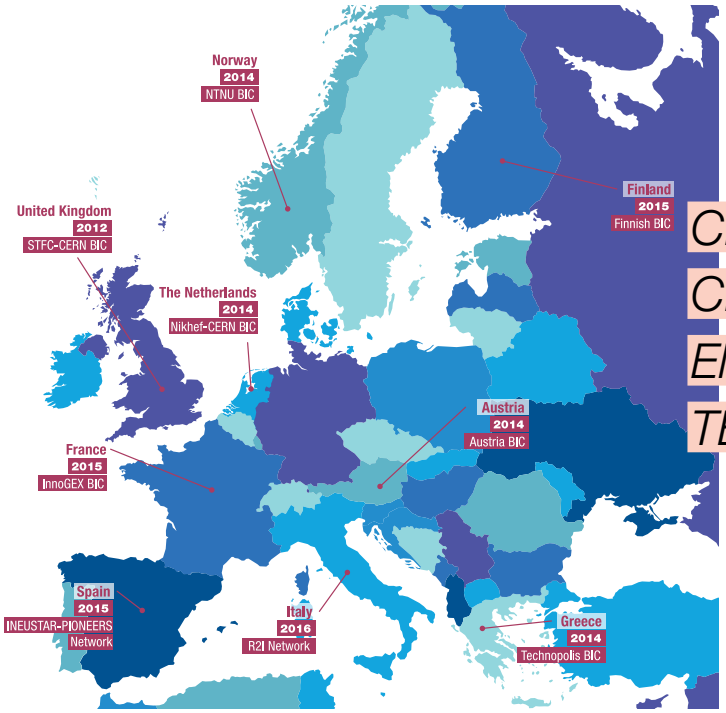
BUSINESS INCUBATION CENTRES

CERN has established a network of nine Business Incubation Centres (BICs) throughout its Member States, to assist entrepreneurs and small technology businesses in taking CERN technologies and expertise to the market.

In practice, CERN supports the selected companies through technical visits to CERN, technical consultancy or services, and preferential rate licensing of CERN intellectual property. The BIC manager provides office-space, expertise, business support, access to local and national networks and support in accessing finance.

There are currently 18 start-ups and spin-offs using CERN technologies for their business. In 2016, 23 startup companies made expressions of interest for entering six of our BICs.

Are you an entrepreneur or a small technology business interested in taking CERN technologies to the market? Find out more at kt.cern/bic-network.



CERN'S BUSINESS INCUBATION CENTRES PROVIDE SUPPORT TO ENTREPRENEURS AND SMALL TECHNOLOGY BUSINESSES.

2016 MEETING OF THE BIC NETWORKS

For the second year running, the managers of the Business Incubation Centres of CERN technologies met in person with CERN's Knowledge Transfer representatives, this time at the STFC-CERN BIC. The meeting provided an opportunity to exchange best practices to foster entrepreneurship related to CERN technologies. Participants discussed concrete actions to increase the number of companies in the CERN BICs. These included suggestions of universities offering entrepreneurship or MBA courses that could be interested in jointly organising courses. Another lead included information on industry associations and small and medium enterprise (SME) networks useful to identify potential BIC candidates.

ITALY JOINS THE CERN BIC NETWORK

CERN signed its ninth Business Incubation Centre agreement with the Italian National Institute of Nuclear Physics (INFN) in June 2016. The agreement will bring together innovators from academia, business and technology. CERN and INFN will jointly set up a network of Italian BICs called the "Research to Innovation" (R2I) Network, composed of local offices in already established Italian BICs. INFN will act as the coordinator of the Italian BICs, who will have access not only to CERN's expertise, but also to the international BIC network set up by CERN.

HOW CAN COMPANIES ENTER A CERN BIC ?

Companies can directly contact a local CERN BIC to express their interest in adopting a CERN technology. CERN's Knowledge Transfer group assists in identifying the most suitable CERN technology and the BIC assesses the feasibility of the company's business plan. If all parties are satisfied that the conditions for joining the BIC are met, a knowledge transfer agreement is signed between CERN and the company, who can then start its incubation programme with the BIC. The incubation lasts from six months to two years depending on the circumstances and includes funding. The company aims to become fully autonomous upon graduation from the programme.

START-UPS AND SPIN-OFFS USING CERN TECHNOLOGIES

START-UPS ACCEPTED INTO A BIC IN 2016

ROSS ROBOTICS

Ross Robotics is a start-up company developing a sophisticated robotics platform, exploiting CERN robotics software originally developed and deployed for production tasks at CERN. Their innovative modular hardware approach needed software to perform a wide range of tasks in an autonomous manner and such software was exactly what CERN had developed for the needs of the LHC. Ross Robotics signed a licence agreement on the CERN robotic software in 2016.

Year founded: 2015
Sector: Robotics
Hosted at the STFC-CERN BIC
Find out more at robosynthesis.com

INNOCRYST

Innocryst is a CERN spin-off developing a system based on X-ray diffraction imaging technology, used to identify and track individual natural and man-made gemstones. The system benefits from the widely used MonteCarlo simulation software framework, FLUKA, originating from a collaboration between CERN and INFN.

Year founded: 2013
Sector: Detector Systems
Hosted at the STFC-CERN BIC
Find out more at innocryst.com

COLNEC HEALTH

Colnec Health is developing a real-time clinical and behavioural data management e-health system to improve the care and follow up of people with chronic diseases. It is using CERN's unique know-how in Grid middleware technology. The start-up offers a new approach to care: shared, continuous, supported, collaborative and interactive among all stakeholders.

Year founded: 2016
Sector: Medtech
Hosted at the InnoGEX BIC
Find out more at colnec.com

CAMSTECH

Camstech is a CERN spin-off commercialising a novel electrochemical sensor technology, initially for research within life sciences and successively for applications in biotechnology and medical diagnostics. In order to scale up and manufacture the sensors, they have licenced technology originally used on the LHC upgrade.

Year founded: 2014
Sector: Biotech
Hosted at the STFC-CERN BIC
Find out more at camstech.co.uk

CURRENT BIC INCUBATEES

TERABEE

Terabee started off providing aerial inspections and imaging services by deploying drones. After a fruitful collaboration with CERN, where sensors were made to ensure the safety of operations in the complex environments of the LHC, its business was expanded to include sensor development. In 2016, the start-up, among others, won the prestigious first place in the automation category of STARTUP WORLD at AUTOMATICA.

Year founded: 2012
Sector: Industrial Robotics
Hosted at the InnoGEX BIC
Find out more at terabee.com

NEUSCHNEE

Neuschnee is an Austrian start-up exploring and developing equipment for snow and ice production for various applications. As they produce machine-made snow by mimicking snowflake growth from water particles, CERN's unique expertise from modelling particles in Computational Fluid Dynamics has led to a fruitful collaboration.

Year founded: 2014
Sector: Machine-made snow
Hosted at the Austria BIC
Find out more at neuschnee.co.at

TIND

TIND is a CERN spin-off providing solutions for library management and data preservation based on the CERN open source software Invenio. 2016 marked the completion of TIND's second full year in business, and they have now permanently expanded their operations in the United States, opening an office in Palo Alto, California.

Year founded: 2013
Sector: Library management & Digital Preservation
Hosted at the NTNU BIC
Find out more at tind.io

CROFT ADDITIVE MANUFACTURING

Croft Additive Manufacturing (CAM) is a CERN spin-off using 3D-printing to deliver innovative filter media designs. Cooperating with CERN scientists, CAM has been able to deliver new part specifications to its customers. Consequently, 2016 has seen its customer base develop from prototypes to operational components, from multiple to single parts, and from high-volume production runs to ever increasing numbers of lower-volume production runs.

Year founded: 2012
Sector: Manufacturing
Hosted at the STFC-CERN BIC
Find out more at croftam.co.uk

"OUR PRESENCE IN THE BIC WAS A DOOR OPENER, AND BROUGHT MANY NEW NETWORKING OPPORTUNITIES TO OUR BUSINESS."

JOHN LEWIS MANAGING DIRECTOR OF 2DHEAT, 2016 STFC-CERN BIC GRADUATE.

START-UPS ASSOCIATED WITH CERN

X-SPECTRUM

X-Spectrum, a spin-off from the Medipix Collaboration, develops and provides a fast, high-resolution X-ray camera for high-end research projects at advanced X-ray sources, enabled by the Medipix3 ASIC technology. In 2016, X-Spectrum rolled out the 'Lambda 60K sensor' featuring a single Medipix3 chip allowing gap- and seamless imaging without noise, available with three different types of sensor layers (Silicon, GaAs, CdTe).

Year founded: 2014
Sector: Detector Systems
Find out more at x-spectrum.de

ADVACAM SRO

Advacam SRO, a spin-off from the Medipix collaboration, brings the next generation of radiation imaging detectors to the scientific and industrial market. All their cameras count individual photons in each pixel while measuring energy of the detected radiation. To achieve this they use the technologies from Medipix2, Medipix3 and Timepix3. In 2016 Advacam delivered a small particle tracking detector to NASA, scheduled to fly to the International Space Station in March 2017.

Year founded: 2013
Sector: Detector Systems
Find out more at advacam.com/en

AMSTERDAM SCIENTIFIC INSTRUMENTS

Amsterdam Scientific Instruments (ASI), a spin-off from the Medipix Collaboration, aims to develop, build and deliver the best and most reliable equipment for the photon science community. Based on the Medipix2, Medipix3 and Timepix3 technologies, ASI offers hybrid pixelated detectors for a broad range of applications both for scientific and industrial users.

Year founded: 2011
Sector: Detector Systems
Find out more at amscins.com

OXFORD NANOSYSTEMS

Oxford nanoSystems (OnS) has developed an innovative heat transfer coating which has been tested, using CERN expertise, in the two-phase detector cooling systems of the ATLAS detector. In 2016, OnS worked with multiple international organisations who are looking to implement the nanoFLUX® coating process into their own manufacturing facilities.

Year founded: 2011
Sector: Industrial coating
Find out more at oxfordnanosystems.com/AboutUs.html

X-RAY IMAGING EUROPE

X-ray Imaging Europe (XIE), a spin-off from the Medipix Collaboration, is producing and selling highly efficient semiconductor detectors and electronics for X- and Gamma-rays. XIE is offering Medipix2 and Timepix3 detectors and detector systems, in which they licence technology developed in the framework of the Medipix Collaborations, for the production of the various detectors.

Year founded: 2008
Sector: Detector Systems
Find out more at xi-europe.com

ADAM

The CERN spin-off ADAM was founded to promote scientific know-how and innovations in medical technology for cancer therapy, and is dedicated to the construction and testing of linear accelerators (linacs) for medical purposes. ADAM is using a radio-frequency quadrupole (RFQ) designed at CERN to build the first unit of a linear accelerator for proton therapy.

Year founded: 2007
Sector: Medtech
Find out more at adam-geneva.com

MARS BIO-IMAGING

MARS Bioimaging (MBI) is based on the next generation of X-ray detectors, exploiting the CERN technology Medipix3. MBI has established itself as the world's leading R&D group in spectral molecular imaging. To date MBI has delivered the world's first commercial pre-clinical scanner to customers at biomedical research labs. In 2016, the first pre-clinical scanners that operate with human-ready parameters were delivered to references sites in the US. This human-ready capability enables biomedical researchers to easily translate their results to human healthcare.

Year founded: 2007
Sector: Detector Systems
Find out more at marsbioimaging.com/mars

QUANTUM DETECTORS

Quantum Detectors, a spin-off from the Medipix Collaboration, was founded to promote a wider exploitation of detectors developed for synchrotron radiation, LASER and other large scale facility applications. Their product, the Merlin photon counting detector system is based on the Medipix3 ASIC. In 2016 they, amongst others, launched a new compact Readout System named "Xspress 3 Mini".

Year founded: 2007
Sector: Detector Systems
Find out more at quantumdetectors.com

IJSPEERT INNOVATIVE TECHNOLOGIES

Ijspeert Innovative Technologies is a CERN spin-off commercialising CERN's diaphragm technique for mechanical centring and fixation of objects. The novel technique centres and clamps the objects with help from a stack of plates, resulting in a strong clamping and a precise centring of objects regardless of shape. Originally developed for the alignment of the LHC corrector magnets, the technique has applications in electro-motor assemblies and the construction industry.

Year founded: 2007
Sector: Manufacturing
Find out more at ijspeert.com

2DHEAT

2DHeat is an R&D SME commercialising their innovative 'flat' electric heating elements, offering superior energy efficiency compared to conventional coiled-wire devices. These novel heating elements have applicability to CERN's ultra-high vacuum (UHV) requirements. 2016 has been promising for 2DHeat, with interest coming from a large number of potential industrial clients.

Year founded: 2004
Sector: Manufacturing
Find out more at 2dheat.com

HUMAN EXCELLENCE & EDUCATION

Humans are at the core of all knowledge transfer activities. At CERN, this corresponds in large part to the physicists, engineers and technicians in STEM (Science, Technology, Engineering & Mathematics), who contribute to CERN's scientific and technological advances. There is currently a high demand for STEM-skilled professionals and even a shortage, especially in the technology sector, such as in engineering and computing. This limitation is not easily overcome: the proportion of students going into STEM is not increasing, and the under-representation of women in STEM persists. Beyond CERN's STEM expertise, our human capital is represented in a wide range of other areas of expertise: from legal to finance and administration.

As an important part of the Organization's mission, CERN contributes to making high quality skills available to its Member States, through education, training and outreach with students and teachers alike. Promoting and ensuring diversity is a key element to these activities, which range from the training of theoretical physicists to outreach activities with high school teachers.

THEORETICAL PHYSICS

Theoretical physics may seem an abstract subject, however it is a factory of exceptional human capital with an inspirational role in all intellectual activities. It fuels outreach activities fascinating the public with ideas behind modern theories and providing them with a sense of awe towards science. Armed with advanced mathematical knowledge and unique computing competence, young theorists are highly sought after in finance, consulting and industry.

CERN Theoretical Physics Department in 2016:
44 Fellows
27 Scientific Associates
745 Visiting Scientists

EDUCATION AND TRAINING

Education and training are key pillars of CERN's mission, and a diverse range of programmes for students and graduates is on offer, varying in length and content. Their success is demonstrated by the ever increasing interest shown, with over ten times as many applicants as there are places. CERN strives to attract the best candidates, mindful of diversity in nationality, study domain and gender, and provides successful applicants with a unique and enriching multicultural training environment. This experience gives them the impetus not only to further their careers but also to ensure knowledge transfer between the Organization and its Member States.

MARIE SKŁODOWSKA-CURIE

As a complement to its flagship fellowship programme, Marie Skłodowska-Curie Actions at CERN are funded by the European Commission to train young researchers across Europe, building the careers of tomorrow's leaders in research and industry. In 2016, the wind-down of FP7 and the ramp-up of Horizon 2020 continued. CERN secured funding for one new CERN-coordinated Innovative Training Networks (ITN) based in the Engineering Department and three Individual Fellows (IF) in the Theoretical Physics Department.

EDUCATION AND OUTREACH

CERN aims to increase awareness of its activities and to promote the interaction of science with society. It is committed to informing the general public about CERN activities, engaging with the local community, and inspiring school children, teachers and all citizens. To do this, it engages in a variety of activities, including an online presence, social media, exhibitions, events, guided tours and teacher training. 2016 activities include:

Nearly 200k visitors to CERN's organised tours and museums

100k visitors reached through travelling exhibitions in 7 different countries

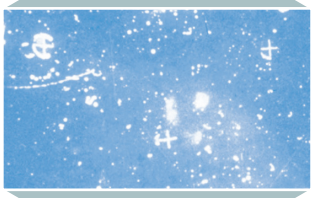
7500 participants in events at the Globe for Science and Innovation

Nearly 1k teachers participating in 35 dedicated programmes

278 students from 87 countries in the Summer Student Programme

4 million unique online visitors, 1.8 million Twitter followers and 1.7 million social media mentions of CERN and the LHC

New "In Theory" and "In Practice" feature articles showcasing some of the people behind the science



INSTITUTE FOR RESEARCH IN SCHOOLS

The Institute of Research in Schools (IRIS) aims to transform the student and teacher experience of science, by involving them in projects with real scientific equipment and data. IRIS was launched at a special event at the Science Museum in London in March 2016. Several projects are related to CERN technologies, through the CERN@school kit. The CERN@school kit uses the Timepix chip developed at CERN by the Medipix2 Collaboration and can be used to measure and image different kinds of radiation. Classroom projects include LUCID (a satellite to study space weather), Radiation Around You (RAY, a radiation monitoring device) and CERN@Sea, which aims to study the radiation around the UK coastline.

Over 250 schools enrolled as participants

Annual Research Symposium celebrates CERN@School and includes talk from high school students

IRIS YouTube channel highlights students' contributions

IBD4HEALTH

IBD4Health, inaugurated in July at E.S.I in Archamps, France, is the latest in a series of BioHealth Computing specialist schools exploring the health applications of scientific computing. Students developed their business ideas into start-up projects and presented them to a panel of experts from diverse disciplines and backgrounds. One project is under consideration for entering a Business Incubation Centre (BIC) for CERN technologies.

BEAMLINE FOR SCHOOLS

The third Beamline for Schools (BL4S) competition took place in 2016. During the year, high school students define a subject for research and formulate a proposal to compete for beamtime. The winners come to CERN and carry out their experiments under the supervision of two support scientists.

151 teams representing 1256 high school students

30 teams that made it to the short list

The winners were two teams from the UK and Poland

"CERN IS A FACTORY OF EXCEPTIONAL HUMAN CAPITAL." GIAN GIUDICE, HEAD OF THE THEORETICAL PHYSICS DEPARTMENT.

COLLABORATIONS

INTERNATIONAL ORGANISATIONS

Thanks to a structured network of relations with other International Organisations (IOs), CERN consolidates the importance of science, scientific education, technology, and innovation as a driving force in the economy and society. CERN also shares with other IOs its experience as a major scientific research institution and benefits in return from their expertise and profile.

SCIENTIFIC ORGANISATIONS

In 2016, CERN continued its cooperation with IOs having a scientific mandate, through bilateral cooperation agreements (e.g., with ITER, ESA, ITU, WMO, WHO, IRENA and ESO) and through EIROforum, a platform of eight major European research institutions (see p56). The first CERN-ESO bilateral meeting was held in November 2016. A CERN-ESO Technology Working Group was established, with a focus on four domains: mechanics, optics, software and systems. CERN's model of science for peace was exported to the Middle East, through strong support for SESAME (Synchrotron-light for Experimental Science and Applications in the Middle East), which came into full operation in 2016 and is based in Jordan.

UNITED NATIONS

Since receiving observer status at the United Nations General Assembly in 2012, CERN maintained in 2016 its strong relationship with the organisation, both at Secretariat level and with the UN specialised agencies. On the Secretariat level, the CERN Director-General continued to serve as a member of the UN Secretary-General's Scientific Advisory Board, which concluded its work late 2016. The focus of science within the United Nations remained a constant message.
The UN's 2030 Agenda for Sustainable Development contains targets to which CERN contributes, for example in the fields of health/medical applications, education and science, IT infrastructure and innovation. In terms of Sustainable Development Goals implementation, CERN could also provide its support to the UN for the finalisation and implementation of the Technology Facilitation Mechanism, especially regarding science and technology related to CERN's activities.

2016 HIGHLIGHTS OF CERN COOPERATION WITH UN SPECIALISED ORGANISATIONS

WIPO: Together with Cornell University and INSEAD, the World Intellectual Property Organisation (WIPO) published the ninth edition of the Global Innovation Index (GII) report in 2016. The theme of the report was "Winning with global innovation" and highlights CERN as an example of successful, regional innovation initiatives. 2016 also saw CERN Director-General join the GII select Advisory Board.

UNESCO: CERN, in coordination with UNESCO, has continued to promote and advocate the role of science and fundamental research. This is an important and necessary investment in the future. A CERN-UNESCO School on digital libraries was organised in November 2016 in Ghana.

UNOSAT: CERN's powerful IT infrastructure is useful for fields other than fundamental research. Since its inception, UNOSAT has been hosted by CERN for the purposes of its humanitarian work. Thanks to this partnership which started 15 years ago, UNOSAT is able to benefit, as and when required, from the Laboratory's IT infrastructure, which allows it to perform cutting-edge analysis of satellite images. This landmark anniversary was celebrated in October 2016 at the UN Headquarters in Geneva. A recorded message of the UN Secretary General, paying tribute to this unique cooperation, was delivered at that occasion.

IPU: In 2016 CERN and IPU, the InterParliamentary Union, developed a Cooperation Agreement that was signed by the two Heads of organisation in November 2016. This agreement is intended to bring science and parliaments closer together, with the objective that parliamentarians adequately include inputs provided and needs expressed by the world of science in the laws they vote, which affect the whole society.

AEROSPACE PARTNERSHIPS

ESTABLISHMENT OF A NEW PARTNERSHIP WITH THE SWISS SPACE CENTER

CERN signed an agreement with the Swiss Space Center (SSC) in June 2016, during a CERN/SSC Technology Transfer event involving representatives from SSC industrial and academic partners. The Swiss Space Center, based at the Swiss Federal Institute for Technology in Lausanne (EPFL) campus, with a hub at ETH Zürich, provides services to facilitate access to space missions and related applications and liaises with the Swiss Space Office. The agreement ensures CERN can benefit from SSC's expertise on space activities and extended network in Switzerland, supporting the transfer of CERN's technologies and expertise to the aerospace field.

SIGNATURE OF A MEMORANDUM OF UNDERSTANDING WITH THE EUCLID CONSORTIUM

In September 2016, a Memorandum of Understanding was signed between CERN and the Euclid Consortium, making the Euclid space mission a CERN Recognised Experiment. Collaborations are ongoing to support the Science Ground Segment. A dedicated seminar was organised in December at CERN to celebrate this collaboration.
Euclid is an ESA space-based survey mission designed to investigate the accelerating expansion of the Universe by measuring the shapes and positions of tens of billions of galaxies. This will generate important amounts of scientific data and the CERN Virtual Machine File System (CernVM-FS) will provide technological solutions (see p12).

TOWARDS A NEXT SPACE PROBE FOR CMB OBSERVATION AND COSMIC ORIGINS EXPLORATION

In May 2016, international Cosmic Microwave Background (CMB) experts met at CERN for a workshop organised by CERN's Knowledge Transfer group in collaboration with the Theoretical Physics (TH) department and the University of Geneva.
The outstanding success of three generations of CMB space missions led to the establishment of the standard model of cosmology and complemented research in fundamental physics done in underground accelerator experiments. During the workshop the science case and concept of the Cosmic ORigin Explorer (CORE) were discussed. CORE is a new space probe proposed to the European Space Agency to measure CMB polarisation with unprecedented performance.

DEFINITION OF A COLLABORATION FRAMEWORK WITH CNES

In 2016, the basis for a long-term framework collaboration agreement between CERN and the French Space Agency CNES (Centre National d'Etudes Spatiales) was established. The identified collaboration priorities include projects related to the use of CERN irradiation facilities for CNES satellite testing, the flight of CERN radiation monitoring technologies on CNES missions, the creation of joint databases, assessment of data handling solutions and organisation of large conferences and thematic workshops in fields of common interest.

KT IN EC CO-FUNDED PROJECTS

Participating projects co-financed by the European Commission (EC) strengthens CERN's existing collaborations and creates new links with European universities, research institutes, laboratories, and industrial partners. These projects often have a knowledge transfer component to them, through collaborative projects, pre-commercial procurement activities, or specific work packages dedicated to innovation and proof-of-concept funding.

JOINT RESEARCH CENTRE - JRC

The Joint Research Centre (JRC) is the scientific and technical arm of the European Commission. Its mission is to provide independent scientific advice and support to EU policy. The JRC initiated the Technology Transfer Office (TTO) Circle, a network bringing together leading public research organisations, including CERN. In May 2016, CERN took part in the European TTO Circle's ninth plenary meeting in San Sebastian. Throughout 2016, CERN and the JRC continued to collaborate in fields relating to big data, medical radioisotope production, and neutron data for nuclear energy applications.

TECHNOLOGY AND INNOVATION MONITOR - TIM

Launched in 2016, CERN and the JRC have developed the Technology and Innovation Monitor (TIM) platform. TIM is a series of technology watch systems to map areas of science and innovation. Among other applications, the tool can be used by energy technology experts to analyse innovation trends in energy technologies. TIM is based on the original idea and concept behind Collaboration Spotting, a novel visual analytics tool developed by CERN to map academic and industry collaborations around key technologies for particle physics.

Find out more at timanalytics.eu

AIDA-2020

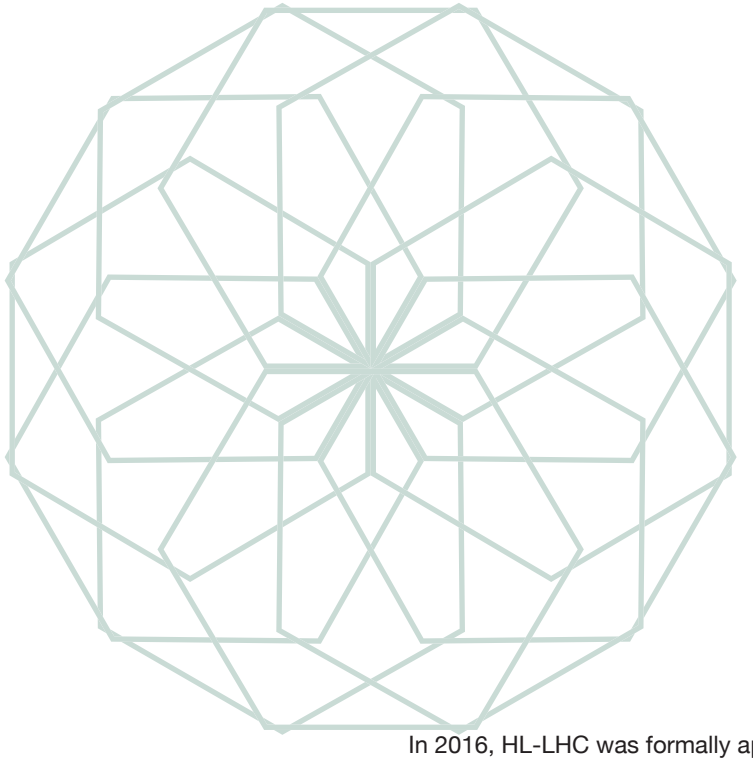
AIDA-2020 stands for "Advanced Infrastructures for Detectors at Accelerators". This EC-funded project began in 2015 and aims to push detector technologies beyond the current state-of-the-art and offer detector testing infrastructures to the scientific and industrial communities. It brings together 38 universities and research laboratories and 21 partner organisations and collaborating institutes. In 2016, a new Proof-of-Concept (PoC) fund set aside € 200k for innovative industry-oriented projects. Three projects were selected with applications in radiotherapy, environmental monitoring and semiconductors.

Find out more at aida2020.web.cern.ch

ATTRACT

ATTRACT is a new, open, pan-EU initiative to accelerate the development of next generation high-performance detection and imaging technologies for fundamental research. ATTRACT operates through a process of co-innovation among European Research Infrastructures and their associated research communities, small and medium enterprises (SMEs), companies and universities.
In 2016, the interest from detection and imaging research communities, industry and business, and innovation experts grew further. Two meetings on Technology Trends, Wishes and Dreams (TWD) were organised at ESADE Business School in Barcelona and Strasbourg. The latter was organised in collaboration with the European Radiation Detection and Imaging Technology Platform (ERDIT) and hosted within the IEEE 2016 NSS/MIC conference. Both events focused on future breakthrough technological developments on a ten to twenty year timescale.

Find out more at attract-eu.org



EUCARD-2

EuCARD-2 stands for Enhanced European Coordination for Accelerator Research & Development. This European project, in which CERN takes part, started in 2013 and connects different large accelerator laboratories. Together with STFC Innovations Ltd, the CERN Knowledge Transfer group leads the work package on “Catalysing Innovation”. An industry workshop was held in Warsaw in December 2016 on “Low-energy electron beams for industrial and environmental applications”. It brought together 70 participants from industry, academia, and research institutes.

Find out more at eucard2.web.cern.ch

ARIES

ARIES stands for “Accelerator Research and Innovation for European Science and Society” and is the successor to EuCARD-2. In 2016, ARIES was approved, and will receive €10M in EU Horizon 2020 funding over a four year period starting in May 2017. ARIES aims to develop novel concepts, to improve existing accelerator technologies and to provide access to top-class accelerator research and test infrastructures for European researchers and industry. ARIES will bring together 41 collaborating institutions from 18 different European countries, CERN and the European Spallation Source (ESS).

HIGH LUMINOSITY LHC

HL-LHC, the High Luminosity LHC, is the project to upgrade the Large Hadron Collider. The higher luminosity will increase the particle interaction rate, extending the LHC’s discovery potential. Some of the HL-LHC key technical challenges require external collaborations: cutting-edge superconducting magnets, ultraprecise superconducting radio-frequency cavities, and high-power superconducting links.

In 2016, HL-LHC was formally approved by the CERN Council. 2016 was the year of the consolidation of the civil engineering and technical infrastructure design with civil engineering plans presented. Several technical milestones were achieved, such as the production of full cross-section models of the HL-LHC’s future quadrupole magnets or the components for the crab cavity cryo-assemblies. Both cases are examples of fruitful international collaboration CERN has established with more than 40 laboratories and universities. In addition to the technical tests, the industrialisation plan for the HL-LHC production was validated by external reviewers.

Find out more at hilumilhc.web.cern.ch

QUACO

QUACO (QUAdrupole Corrector) is a project in HL-LHC dedicated to magnets for insertion regions. HL-LHC requirements include for example “long orbit corrector magnets” (that adjust particle orbits) and “two-in-one quadrupole magnets” (that focus particle beams), which are not currently on the market. Because the potential for commercial application is low at this stage, strategic industry-research collaboration is necessary. QUACO is a pre-commercial procurement (PCP) project where risks and opportunities are shared through a public-private partnership.
In 2016, QUACO achieved many milestones including the organisation of an open market consultation, the signing of a joint procurement agreement, a call for tender for phase 1, the assessment and evaluation of the first PCP phase results as well as the award of a framework contract to four European companies.

Find out more at quaco.web.cern.ch

NETWORKS FOR KNOWLEDGE TRANSFER

ENLIGHT – THE EUROPEAN NETWORK FOR LIGHT ION HADRON THERAPY

The ENLIGHT network, established in 2002, gathers multidisciplinary experts for the advancement of particle therapy for cancer treatment. The annual meeting, held in Utrecht and hosted by Nikhef and the University of Utrecht, was attended by almost 100 participants from 15 countries. At the meeting, the elected members of the newly established advisory committee were announced. For the first time, a day of training on key aspects of particle therapy was included. This was a critical step as more experts are needed in this rapidly expanding field; following its success, a hands-on course will be organized at the next meeting in Denmark, June 2017. Topical news is regularly shared among the community and the CERN Council through the Highlights magazine, which was first published on the occasion of the 10th anniversary.

Find out more at enlight.web.cern.ch

HEPTECH – THE HIGH-ENERGY PHYSICS TECHNOLOGY TRANSFER NETWORK

HEPTech is the high-energy physics technology transfer network (TTN). The network is made up of leading European institutions and universities from 16 different countries. Each of these research organisations works across a range of world-leading scientific areas to meet the intense technological challenges of exploring fundamental particle, astro-particle and nuclear physics. In 2016, HEPTech organised four Academia-Industry Matching Events (AIMEs) in Germany, France, Switzerland and Spain. The AIME concept is now widely recognised as a valuable instrument for fostering exchanges between researchers and industry. In 2016, HEPTech organised its fourth Symposium focused on early-stage researchers with an entrepreneurial potential in high-energy physics. The one-week training programme was designed for researchers with adventurous and entrepreneurial spirit, and was held in Romania. HEPTech also organised events for its members to discuss funding opportunities.

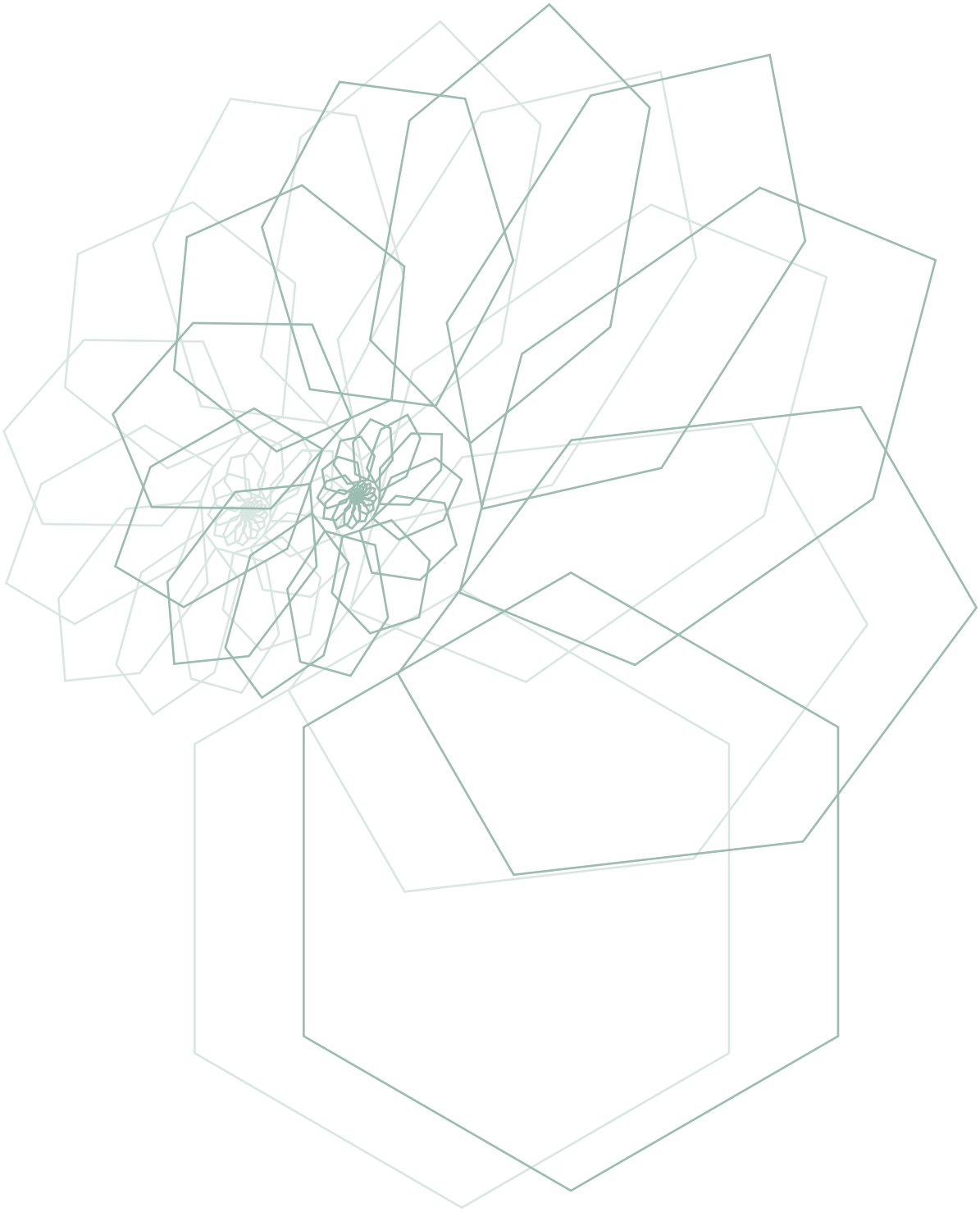
EIROFORUM – SERVING EUROPEAN SCIENCE

EIROforum is an umbrella organisation of eight international research organisations, including CERN. Along with other EIROforum organisations, CERN attended Pollutec 2016, an international exhibition of environmental equipment technologies and services (see p36). The EIROforum's thematic working group on Innovation Management and Knowledge/Technology Transfer (IMKTT), chaired by CERN, organised a stand at the European Science Open Forum (ESOF, see p37) to showcase the positive impact of EIROforum technologies on society.

EIROforum members include: CERN, ESA (European Space Agency), ESO (European Southern Observatory), EMBL (European Molecular Biology Laboratory), ESRF (European Synchrotron Radiation Facility), Eurofusion (European Consortium for the Development of Fusion Energy), European XFEL (European X-ray Free Electron Laser Facility), and ILL (Institut Laue Langevin).

RADSAGA - EXTERNAL SUPPORT FOR TRAINING PROJECTS RELATED TO RADIATION EFFECTS

In May 2016, the RADSAGA proposal ("RADiation and Reliability Challenges for Electronics used in Space, Avionics, on the Ground and at Accelerators") was approved for funding by the EC as a Marie Curie Innovative Training Network (ITN). This initiative will bring together industry, universities, laboratories and test-facilities in order to innovate and train early-career scientists and engineers in aspects related to electronics exposed to radiation. In December 2016, the European Space Agency decided to co-sponsor a PhD student from the University of Oslo in the frame of a Networking/Partnering Initiative. The student will work on the development of a high-fidelity radiation monitoring instrument for small spacecraft, to be characterised in CERN irradiation facilities.



CREDITS

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Find out more at kt.cern

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