CERN knowledge meets business

HL-LHC
LHC Injectors Upgrade project proceeds apace p32

NEUTRINOS
Generators model neutrino-nucleus interactions p23

FOCUS ON SOUTH ASIA
CERN instrumentation workshop engages region p28
CERN has developed a radio-frequency quadrupole for a miniature linear accelerator ideal for medical and industrial applications, with the technology licensed to a spin-off company.

By Giovanni Anelli

Understanding what the universe is made of and how it started are the fundamental questions behind CERN’s existence. This quest alone makes CERN a unique knowledge-focused organisation and an incredible human feat. To achieve its core mission, CERN naturally creates new opportunities for innovation.

A myriad of engineers, technicians and scientists develop novel technology and know-how that can be transferred to industry for the benefit of society. Twenty years ago, with the support of CERN Council, a reinforced structure for knowledge and technology transfer was established to strengthen these activities. Advances in fields including accelerators, detectors and computing have had a positive impact outside of CERN. Although fundamental physics might not seem the most obvious discipline in which to find technologies with marketable applications, the many examples of applications of CERN’s technology and know-how — whether in medical technology, aerospace, safety, the environment and “industry 4.0” — constitute concrete evidence that high-energy physics is a fertile ground for innovation. That CERN’s expertise finds applications in multinational companies, small and medium enterprises and start-ups alike is further proof that CERN’s strategy finds clear evidence that high-energy physics is a fertile ground for innovation.

In the future, CERN will continue to pursue and promote open innovation. We want to build a culture of entrepreneurship whereby more people leaving CERN consider starting a business based on CERN technologies, and use a wide range of metrics to quantify our innovation. Strong links with industry are important to help reinforce a market-pull rather than technology-push approach. The Knowledge Transfer group will also continue to provide a service to the CERN community through advice, support, training, networks and infrastructure for those who wish to engage with industry through our activities.

Human capital is vital in our equation, since knowledge transfer cannot happen without CERN’s engineers, technicians and physicists. Our role is to facilitate their participation, which could start with a visit to our new website, Entrepreneurship Meet-Up (EM-U), or a visit to one of our seminars. Since they were launched roughly two years ago, EM-U and knowledge-transfer seminars have together attracted more than 2000 people. Whether you want to tell us about an idea you have, or are curious about the impact of our technologies on society, we hope to hear from you soon.

Find out more at kt.cern.
The core mission of CERN is fundamental research in particle physics. Yet, as a publicly funded laboratory, it also has a remit to ensure that its technology and expertise deliver prompt and tangible benefits to society wherever possible. Other physics-research laboratories and institutes were early adopters of CERN technologies, thanks to the highly collaborative nature of particle physics.

Since its creation in 1954, CERN has also been active in transferring technology to industry, mainly through purchasing contracts or collaboration agreements. Through novel developments in the field of accelerator technologies and detectors, and more recently in computing and digital sciences, CERN technologies and know-how have contributed to applications in many fields, including the World Wide Web, invented at CERN by Tim Berners-Lee in 1989.

As its impact has broadened, in 1997 CERN set up a reinforced policy and team to support its knowledge- and technology-transfer activities. Twenty years later, these activities are still going strong. Some 18 start-up companies around the world are currently using CERN technology and CERN has developed a network of Business Incubation Centres (BICs) in nine different Member States. Its knowledge-transfer activities have impacted a wide range of fields, from medical and biomedical technologies to aerospace applications.

Maximising the societal impact of CERN technologies is a key aim for CERN’s knowledge-transfer activities. To do this...

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The Timepix3 chip is a multipurpose hybrid pixel detector developed within the Medipix3 collaboration, having applications to medical imaging, education, space dosimetry and materials analysis. (Image credit: M Brice/CERN.)
Cutting-edge medical technologies under CERN’s microscope

Novel designs for compact medical accelerators

Thanks to cutting-edge studies on beam dynamics and radio-frequency technology, along with innovative construction techniques, teams at CERN have manufactured an innovative linear accelerator designed to be compact, modular, low-cost and suitable for medical applications. The accelerator is a radio-frequency quadrupole (RFQ) operating at a frequency of 750 MHz, which had never been achieved before, and capable of producing low-intensity beams of just a few microamps with no significant losses. The high-frequency RFQ capitalises on the skills and know-how developed at CERN while designing Linac 4, and is a perfect injector for the new generation of high-frequency compact linear accelerators being developed for hadron therapy.

Expertise in high-gradient accelerating structures gathered by the Compact Linear Collider (CLIC) group at CERN is also being applied to novel designs for hadron-therapy facilities, such as the cyclic concept proposed by the CERN Foundation, and finally evolved into the machine built for the CNAO and MedAustron treatment centres, in particular with expertise in accelerators and magnets and with training of personnel.

For the past 50 years, CERN has hosted the ISOLDE facility dedicated to the production of a large variety of radioactive ion beams for different experiments in the fields of nuclear and atomic physics, solid-state physics, materials science and life sciences. Over 1200 radioisotopes from more than 70 chemical elements have been made available for fundamental and applied research, including in the medical field. A particular highlight was the demonstration in 2012 of the efficiency of terbium-149, one of the highest alpha emitters, for treatment at the level of single cancer cells. The growing worldwide interest in novel isotopes suitable for theranostics, namely the possibility to perform both imaging and treatment at the same time, has motivated an extension of ISOLDE called CERN-MEDICIS (Medical Isotopes Collected from ISOLDE). This new facility will produce, as of this autumn, innovative isotopes for performing medical research at collaborating institutes (CERN Courier October 2016 p28).

Today, activities pertinent to medical applications are happening in all areas of CERN, with some compelling examples highlighted in the panel ‘Technology for health’ at CERN Council approved a document setting out the “Strategy and framework applicable to knowledge transfer by CERN for the benefit of medical applications”.

Aiming high

Aerospace and particle physics might not at first seem obvious partners. However, both fields are working in extreme environments, posing stringent technological requirements that are often similar. CERN operates testing facilities and develops qualification technologies for high-energy physics, which are useful for ground testing and qualification of flight equipment. This opportunity is particularly attractive for miniaturised satellites called Cubesats that typically use commercial off-the-shelf components for their electronics, since radiation qualification according to standard procedures is expensive and time-consuming.

The CERN Latchup Experiment Student’s Satellite (CELESTA) intends to develop a CubeSat version of RadMon, a radiation monitor developed at CERN, and to prove that low-Earth orbit qualification can be performed in CERN’s High-energy Accelerator Mixed field facility (CHARM). CELESTA is being developed in collaboration with the University of Montpellier and this year was selected by ESA’s “Fly Your Satellite!” programme to be deployed in orbit in 2018 or 2019.

Magnetism diboride (MgB$_2$), the high-temperature superconductor that will be used for the innovative electrical transmission lines of the high-luminosity LHC, has also demonstrated its potential for future space missions. Within the framework of the European Space Radiation Supervising Shield (PIMMS) project, which aims to demonstrate the feasibility of using superconducting magnetic shielding technology to protect astronauts from cosmic radiation, CERN successfully tested a prototype.

Medipix3 is a CMOS pixel detector read-out chip designed to be connected to a segmented semiconductor sensor. Like its predecessor, Medipix2, it acts as a camera taking images based on the number of particles that hit the pixels when the electronic shutter is open. However, Medipix3 aims to go much further than Medipix2 by permitting colour imaging and dead-time free operation. Ten years ago, a member of the Medipix3 collaboration founded a company in New Zealand and obtained a licence to exploit the chip for spectral computed tomography imaging — X-Ray imaging in colour. The company’s pre-clinical scanners enable researchers and clinicians to study biochemical and physiological processes in specimens and small animals. In a related development, the IPEsac chip permits trigger-free particle tracking in a single semiconductor layer. Preliminary measurements using the previous generation of the chip strongly hint to its potential for beam and dose monitoring in the hadron-therapy environment.

Since 1997, CERN’s Crystal Clear collaboration (CCC) has been using its expertise in scintillators to develop and construct PET prototypes. Their first success was the ClearPET concept: the development of several prototypes has resulted in the commercialisation of a small-animal scanner with breakthrough performance and led to the first simultaneous PET/CT image of a mouse in 2015. Starting in 2002, the CCC started developing dedicated PET scanners for breast imaging, called ClearFEM, with two prototypes emerging currently. All investigations are focused on time-of-flight PET scanners for better image quality. Via the European FP7 project EndOTOPET, USA, CCC members are developing a novel bi-modal time-of-flight PET and an ultrasound-endoconeype prototype dedicated to early-stage detection of pancreatic and prostate cancer.

Computing and simulations

Monte Carlo simulations are essential for radiotherapy treatment planning.

Simulation codes initially developed for HEP, such as Geant4 and FLUKA, have also become crucial to modelling the effects of radiation on biological tissues for a variety of applications in the medical field. FLUKA is licensed to various companies in the medical field; in particular, FLUKA-based physics databases are at the core of the commercial treatment planning systems (TPS) clinically used at HT and CNAO, as well as of the TPS for carbon ions for MedAustron. Geant4 is adopted by thousands of users worldwide for applications in a variety of domains: examples of Geant4 extensions for use in the medical field are GATE, TOPAS and Geant4-ON.$^A$

Computing tools, infrastructures and services developed for HEP have also great potential for applications in the medical field. CERN openlab has recently started two collaborative projects in this domain: BioSyncMa aims to design and build a cloud-based computing platform for rapid simulation of biological tissue dynamics, such as brain development; GenoROOT aims to use ROOT to analyse large genomics data sets, beginning with data from TwinsUK, the largest UK adult twins registry.
CERN’s expertise builds broadly on three technical fields: accelerators, detectors and computing. Behind these three pillars of technology lie many threads of technology and human expertise that translate into positive impacts on society in many different fields. (Image credit: G Dorne/CERN)

effectively, CERN has set up a thematic forum with delegates from all of its Member States and associate Member States. Regular meetings are held at CERN, and beginning this year there will also be forum meetings dedicated to medical applications – which is one of the most prominent examples of CERN’s impact so far.

Technology for health

Early activities at CERN relating to medical applications date back to the 1970s, and have been triggered for the most part by individual initiatives. The multiwire proportional chamber conceived in 1968 by CERN physicist Georges Charpak not only opened a new era for particle physics and led to his Nobel Prize in Physics, but also found important X-ray and gamma-ray imaging applications in biology, radiology and nuclear medicine. Essential early work at CERN also contributed significantly to the development of advanced detectors and analysis techniques for positron emission tomography (PET). In particular, starting in 1975 with famous images of a mouse, CERN physicist David Townsend led important contributions to the reconstruction of PET images and to the development of 3D PET in, in collaboration with the University of Geneva and the Geneva Cantonal Hospital.

After these individual efforts, in the 1990s CERN witnessed the first collaborative endeavours in medical applications. The Crystal Clear and Medipix collaborations started to explore the feasibility of developing technologies used in the LHC detectors – scintillating crystals and hybrid silicon pixel detectors, respectively – for possible medical applications, such as PET and X-ray imaging. At the same time, the Proton Ion Medical Machine Study (PIMMS) which initiated at CERN, with the aim of producing a synchrotron design optimised for treating cancer patients with protons and carbon ions. The initial design was improved by the TERA Foundation, and finally evolved into the machine built for the CNAO treatment centre in Italy, with seminal contributions from INFN. Later on, MedAustron in Austria built its treatment centre starting from the CNAO design. Beyond the initial design study, CERN contributed to the realisation of the CNAO and MedAustron treatment centres, in particular with expertise in accelerators and magnets and with training of personnel.

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Simulation codes initially developed for HEP, such as Geant4 and FLUKA, have also become crucial to modelling the effects of radiation on biological tissues for a variety of applications in the medical field. FLUKA is licensed to various companies in the medical field: in particular, FLUKA-based physics databases are at the core of the commercial treatment planning systems (TPS) clinically used in CT and MR, while as of the TPS for carbon ions for MedAustron. Geant4 is adopted by thousands of users worldwide for applications in a variety of domains: examples of Geant4 extensions for use in the medical field are GATE, TOPAS and Geant4-DNA.

Computing tools, infrastructures and services developed for HEP have also great potential for applications in the medical field. CERN openlab has recently started two collaborative projects in this domain: BioDynaMo aims to design and build a cloud-based computing platform for rapid simulation of biological tissue dynamics, such as brain development; GeneROOT aims to use ROOT to analyse large genomic data sets, beginning with data from TwinsUK, the largest UK adult twins registry.

Knowledge transfer

Cutting-edge medical technologies under CERN’s microscope

Novel designs for compact medical accelerators

The first brazed RFQ module for medical applications.

Thanks to cutting-edge studies on beam dynamics and radio-frequency technology, along with innovative construction techniques, teams at CERN have manufactured an innovative linear accelerator designed to be compact, modular, low-cost and suitable for medical applications. The accelerator is a radio-frequency quadrupole (RFQ) operating at a frequency of 750 MHz, which had never been achieved before, and capable of producing low-intensity beams of just a few microamps with no significant losses. The high-frequency RFQ capitalises on the skills and know-how developed at CERN while designing Linac 4, and is a perfect injector for the new generation of high-frequency compact linear accelerators being developed for hadron therapy.

Expertise in high-gradient accelerating structures gathered by the Compact Linear Collider (CLIC) group at CERN is also being applied to novel designs for hadron-therapy facilities, such as the cyclotron concept proposed by the TERA foundation, as well as the development of accelerators to boost the energy of medical cyclotron to provide proton-imaging capabilities. CERN’s know-how in cryogenic systems is also interesting for modern superconducting medical accelerators, such as the compact cyclotron being developed by CEMAT for on-site production in hospitals of isotopes for PET.

Detectors and medical imaging

Dense, precision-grown crystals for the CMS experiment.

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Knowledge transfer

CERN technologies and know-how have found concrete applications in a variety of other fields. One of them is safety: CERN’s unique working environment, which combines various types of radiation, extremely low temperatures, ultra-high magnetic fields and very high voltages, requires innovative solutions for detecting threats and preventing risks. An example is B-rad, a portable meter to ensure radiation safety in strong magnetic fields that was initially developed by CERN’s radiation-protection group and fire brigade. With a financial contribution from the CERN Knowledge Transfer (KT) Fund, the product has been brought from lab prototype to finalised product in collaboration with an Italian company. Another example is Kryosite, a novel cryogenic safety software also developed in CERN’s Radiation Protection Division. Its Kryosite licences have now been granted to other research laboratories, with potential applications ranging from the food industry to cryogenic techniques in medicine.

CERN also taps into its technologies and creativity to address the challenge of a healthier and more sustainable planet. CERN’s contribution in this area ranges from novel biochemical sensors for water safety through new information technologies for the most challenging agricultural environments. The innovative Non Evaporable Getter (NEG) technology developed to reach ultra-high-vacuum conditions in the LHC vacuum chambers, for example, was successfully used in other applications, including thermal solar panels.

MgB2-based superconducting power cables could also offer significant power transmission solutions for densely populated, high-load areas, and CERN is part of a consortium to build a prototype to demonstrate the feasibility of this concept. Another buzz-worthy trend in the industry is the so-called “industry 4.0”, a push towards 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 naturally 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. In the field of robotics, CERN has developed TIM (Train Inspection Monorail), a mini vehicle autonomously monitoring the 27 km-long LHC tunnel and moving along tracks suspended from the tunnel’s ceiling, which can be programmed to perform real-time inspection missions. This innovation has already caught the eye of industry, in particular for automating monitoring of utilities infrastructure, such as underground water pipelines. Sensor technologies developed at CERN are also being used in drones, such as in the start-up Terabee, which uses them for aerial inspections and imaging services. Since their business was expanded to include CERN sensor development, the start-up won the prestigious first place in the automation category of Startup World at Automatika.

Boosting KT in practice

One of the main challenges in the knowledge-transfer sphere is to make it as easy as possible for scientists and other specialists to turn their research into innovations, and CERN invests much effort in such activities. Launched in 2011, the CERN KT Fund bridges the gap between research and industry by awarding grants to projects proposed by CERN personnel where there is high potential for positive impact on society. Since its creation, 40 projects have been funded, each receiving grants with a value of CHF15-240 thousand over a period of one or several years. Among them were projects addressing thermal management in space applications, very large-scale software distribution, distributed optical-fibre EDF, and long-term data preservation for libraries. In 2016, two European Commission funded projects, AIDA-2020 and ARIES, incorporated a proof-of-concept fund modelled on CERN’s KT Fund.

Since the early days of technology transfer at CERN, one of the main focuses has been on knowledge transfer through people, especially early career scientists who work in industry after their contract. CERN or who start their own company. Over the last 20 years, CERN has continued to build a general culture of entrepreneurship within the Organization through many different avenues. To assist entrepreneurs and small technology businesses in taking CERN technologies and expertise to the market, CERN has established a network of nine BICs throughout its Member States where companies can directly express their interest in adopting CERN technology. The BIC managers provide access to office space, expertise, business support, access to local and national networks and support in accessing funding. There are currently 18 start-ups and spin-offs using CERN technologies in their business, with four joining BICs last year alone: Ross Robotics (exploiting software developed for production tasks at CERN); Innocyst (developing a system to identify and track gemstones); CoInHealth (using CERN’s know-how in epigenetic technology) and Camstech (novel electrochemical sensor technologies).

Every year since 2008, students from the School of Entrepreneurship (NSE) at the Norwegian University of Science and Technology (NTNU) spend a week at CERN to work on the business commercial potential of CERN technologies. Three of the students attending the CERN-NTNU screening week in 2012 started the spin-off TEND, which is based on the CERN software Invenio. TIND has now, among others, contracts to host Invenio for the UNESCO International Bureau of Education, the California Institute of Technology and the Max Planck Institute for Extraterrestrial Physics.

Owing the next generation of scientists into the habit of thinking about their research in terms of impact is vital for knowledge transfer to thrive. In 2015, CERN launched a series of Entrepreneurs’ Uplift programmes to foster entrepreneurship at the CERN community. Selected CERN and external entrepreneurship experts present their expertise at informal get-togethers and the events offer a good opportunity to network. In October this year, the EMs are celebrating their 50th event, with over 1000 attendees since the series was created, and a new informal “KT-clinic” service has been launched.

Many more interesting projects are in the pipeline. CERN’s knowledge in superconducting technologies can be used in MRI and gantries for hadron therapy, while its skills in handling large amounts of data can benefit the health sector more widely. Detector technologies developed at CERN can be used in non-destructive testing techniques, while compact accelerators benefit the analysis of artworks. These are just some of the examples of new projects we are working on which will be started with the help of industrial and research partners in CERN’s Member States and associate Member States for the next 20 years and beyond.

A brief history of knowledge transfer at CERN

• 1954: Since its creation, CERN has been active in knowledge transfer, although with no formal structure.
• 1974 & 1983–1984: Two external studies consider the economic impact of CERN contracts and find that it equates to around 3–3.5 times the contract value.
• 1987: CERN’s Annual Report incorporates the first dedicated section on technology-transfer activities.
• 1988: The Industry and Technology Liaison Office (TLO) is founded at CERN to stimulate interaction with industry, including through procurement.
• June 1997: With the support of Council, CERN sets up a reinforced structure for technology transfer.
• November 1997: The Basic Science and Technology Transfer: Means and Methods in the CERN Environment workshop helps to identify appropriate technology-transfer mechanisms.
• November 1998: CERN develops a network to support intellectual-property rights protection practices that was endorsed by the finance committee.
• 1999: First technology-transfer policy at CERN, with the new technology-transfer service replacing the TLO and three main actions: to encourage the protection of intellectual-property rights for new technologies developed at CERN and the institutes participating in its scientific programme; to promote the training of young scientists in intellectual property rights; and to promote entrepreneurship.
• 2001: CERN begins to report on its technology-transfer activities annually to the CERN finance committee.
• 2008: creation of HEPTECH, a technology-transfer network for high-energy physics.
• 2010: CERN develops a new policy on the management of intellectual property in technology-transfer activities at CERN.
• 2014: A new technology-transfer service is created to ensure the effective management of technologies developed at CERN.
• 2019: CERN publishes new medical-applications strategy, works on a set of updated software and spin-off and patent policies, and launches a revamped knowledge-transfer website: kt.cern.

Résumé

Du web à des entreprises proches de vous

La recherche fondamentale en physique des particules constitue la mission principale du CERN. Toutefois, le CERN étant un laboratoire financier par des fonds publics, il doit également faire figure que, dans la mesure du possible, ses technologies et ses compétences apportent des bénéfices à la société. A y 20 ans, l’Organisation a intensifié ses efforts dans le domaine du transfert de connaissances et de technologies ; ceux-ci ont déjà produit de centaines d’accords de collaboration et des dizaines de nouvelles entreprises, dans des secteurs allant des technologies médicales à l’aéronautique.

Anais Rassat et Manuela Grilli, CERN.
Knowledge transfer

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The early days of technology transfer at CERN, one of the main focuses has been on knowledge transfer through people, especially early career scientists who work in industry after their PhD, and CERN or who start their own company. Over the last 20 years, CERN has continued to build a general culture of entrepreneurship within the Organization through many different avenues. To assist entrepreneurs and small technology businesses in taking CERN technologies and expertise to market, CERN has established a network of nine BICs throughout its Member States where companies can directly express their interest in adopting a CERN technology. The BIC managers provide access to relevant expertise, business support, access to local and national networks and support in accessing funding. There are currently 18 start-ups and spin-offs using CERN technologies in their business, with four joining BICs last year alone: Ross Robotics (exploiting software developed for production tasks at CERN); Innopack (developing a system to identify and track gemstones); Colne Health (using CERN’s Medipix and TimePix technology and the Mag3B-based superconducting tape for medical imaging); and Camtech (novel electrochemical sensor technologies). Every year since 2008, students from the School of Entrepreneurship (NSE) at the Norwegian University of Science and Technology (NTNU) spend a week at CERN to work on the business commercial potential of CERN technologies. Three of the students attending the CERN-NTNU screening week in 2012 started the spin-off TEND, which is building a secure software Invenio. TIND now has, among others, contracts to host Invenio for the UNESCO International Bureau of Education, the California Institute of Technology and the Max Planck institute for Extraterrestrial Physics. To further the next generation of scientists into the habit of thinking about their research in terms of impact is vital for knowledge transfer to thrive. In 2015, CERN launched a series of Entrepreneurship Workshops to foster entrepreneurial initiatives within the CERN community. Selected CERN and external entrepreneurial experts present their expertise at informal get-togethers and the events offer a good opportunity to network. In October this year, the EM-Us are celebrating their 50th event, with over 1,000 attendees since the series was created, and a new informal “KT-clinic” service has been launched.

Knowledge transfer

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The CELESTA CubeSat payload module ready for radiation testing in CERN’s CHARM facility.

A prototype racetrack coil wound with a MgB₂ superconducting tape. Astronauts’ exposure to space radiation is a major concern for future crewed missions to Mars and beyond. Monte Carlo codes such as FLUKA, initially jointly developed by CERN and INFN, and Granat, developed and maintained by a worldwide collaboration with strong support from CERN since its conception, have been routinely used to study the radiation environment of past, recent, and future space missions. The TimePix detectors, which are USB-powered particle trackers based on the Medipix technology, are already used by NASA on board the International Space Station to accurately monitor radiation doses. CERN’s computing expertise is also finding applications in aerospace. To solve the challenge of sharing software and codes in big-data environments, researchers at CERN have developed a system called CERNVM-FS (CERN Virtual Machine File System), which is currently used in high-energy physics experiments to distribute about 350 million files. The system is now also being used for Euclid, a European space mission that aims to study the nature of dark matter and dark energy, to deploy software in Euclid’s nine space data centres.

CERN technologies and know-how have found concrete applications in a variety of other fields. One of them is safety: CERN’s unique working environment, which combines various types of radiation, extremely low temperatures, ultra-high magnetic fields and very high voltages, requires innovative solutions for detecting threats and preventing risks. An example is B-radar, a portable meter to ensure radiation safety in strong magnetic fields that was initially developed by CERN’s radiation-protection group and fire brigade. With a financial contribution from the CERN Knowledge Transfer (KT) Fund, the product has been brought to prototype to finalised product in collaboration with an Italian company. Another example is Kryolize, a novel cryogenic safety software also supported by CERN. Kryolize accelerators, detectors and computing facilities naturally 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. In the field of robotics, CERN has developed TIM (Train Inspection Monitor), a mini vehicle autonomously monitoring the 27 km-long LHC tunnel and moving along tracks suspended from the tunnel’s ceiling, which can be programmed to perform real-time inspection missions. This innovation has already caught the eye of industry, in particular for autonomous monitoring of utilities infrastructure, such as underground water pipelines. Sensor technologies developed at CERN are also being used in drones, such as in the start-up Terabee, which uses them for aerial inspections and imaging services. Since their business was expanded to include CERN sensor development, the start-up won the prestigious first place in the automation category of StartUp World at Automatica.

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