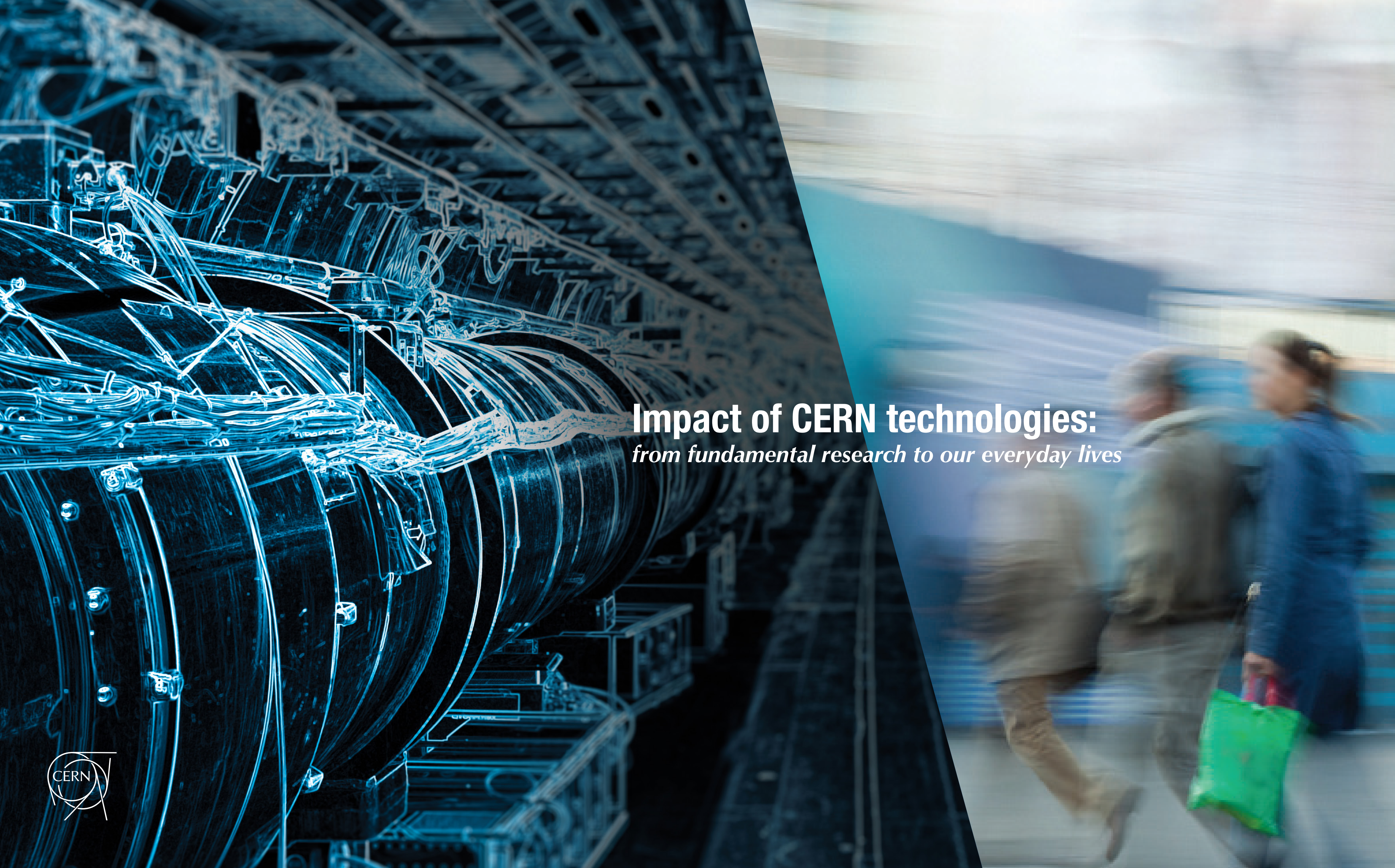

Impact of CERN technologies:

from fundamental research to our everyday lives

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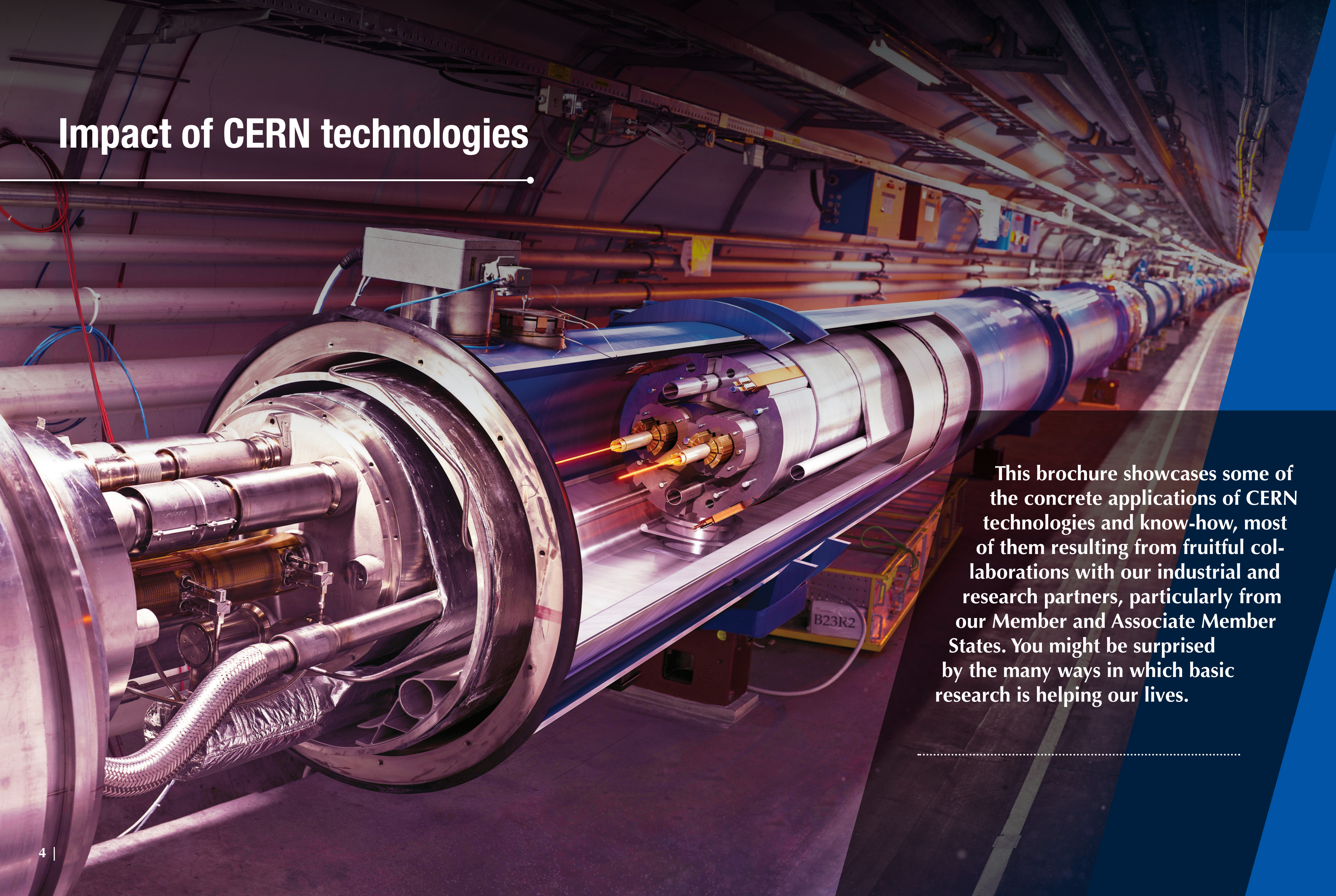
Impact of CERN technologies



This brochure showcases some of the concrete applications of CERN technologies and know-how, most of them resulting from fruitful collaborations with our industrial and research partners, particularly from our Member and Associate Member States. You might be surprised by the many ways in which basic research is helping our lives.

CERN technologies: from fundamental research to our everyday lives

Since 1954, the world-class research performed at CERN helps uncover what the universe is made of and how it works: here, scientists from all over the world study elementary particles – invisible to the eye – through complex and often gigantic instruments.

Such fundamental research seems distant from our everyday lives. Yet, the international dimension of CERN, run by its Member States, the global nature of the experiments hosted by the Laboratory, and the unique collaborative environment of particle physics provide fertile ground for innovations that benefit society at large: take the World Wide Web, invented at CERN in 1989 to ease information sharing among scientists; since then, it has helped to connect billions of people around the globe.

Particle-physics research acts as a trailblazer for disruptive technologies related to particle accelerators, particle detectors, and computing. These technologies are much more widespread than you might think: while there is only one 27-kilometre long Large Hadron Collider (LHC), there are tens of thousands of much smaller particle accelerators used in industry and healthcare.

Particle accelerators

They propel beams of particles almost to the speed of light before the beams are made to collide with each other or with stationary targets. CERN's Large Hadron Collider is the largest and most powerful accelerator in the world, boosting protons in a 27-kilometre loop.

Particle detectors

They act as giant, high-speed cameras, taking 3D digital "photographs" of particle collisions. By studying the outcome of these collisions, physicists probe the world of the infinitely small.

Computing

CERN's demanding needs encompass software development, data processing and storage, networks, support for the experimental programme, automation and controls, as well as services for the whole laboratory and its users.

Technologies for healthcare innovation

Particle accelerators, a formidable tool for cancer treatment

Today, there is no single therapy that works for every type of cancer. Radiotherapy is one of the treatment options in the doctors' toolbox: it damages cancer cells by exposing them to high doses of radiation and is often delivered by the same technology that accelerates particles at CERN and in other laboratories. In numerous hospitals, conventional radiotherapy is performed with room-sized particle accelerators that target tumours with beams of X-rays.

Besides X-rays, other particles have interesting properties that could allow better treatment of certain types of tumours or a reduction of harmful side effects: these include protons, electrons, and ions such as carbon or helium. New radiotherapy modalities are also being explored: for example, FLASH irradiation, whereby ultra-high radiation doses are delivered over extremely short time periods, seems to strongly reduce damage to healthy tissues.

Widespread adoption of these innovative treatments is often limited by the cost and complexity of the instruments needed, and this is where CERN's expertise in the development of advanced accelerator and magnet technology can help make a difference.

In the 1990s, CERN hosted a collaborative design study, made publicly available, of a novel circular accelerator capable of delivering therapeutic beams of both protons and carbon ions. With further enhancements from the TERA foundation and seminal contributions from INFN, the study evolved into the blueprint for the National Center for Oncological Hadrontherapy (CNAO), whose design then provided the basis for the MedAustron centre.

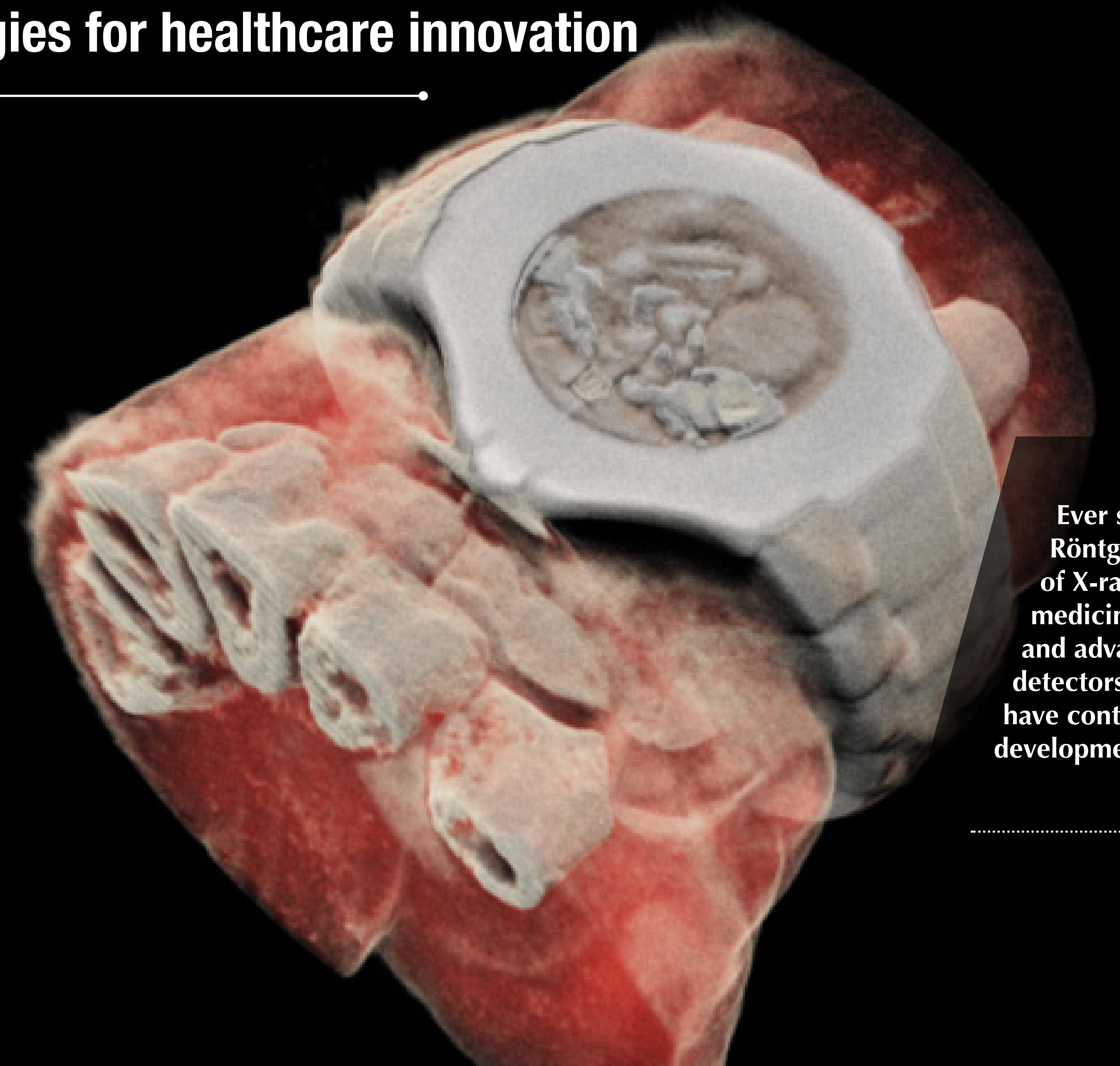
CNAO and MedAustron are two of the only four centres in Europe that can provide both protons and carbon ions, and have now treated thousands of patients. Over the years, CERN has been providing its technical expertise to these clinics and continues to collaborate with them and with a broad community of international partners to develop technologies for next-generation particle therapy machines: more compact, less expensive, and capable of providing even more treatment options.

The option of linear accelerators is also being explored. CERN's know-how in this field has been directly applied to the development of an innovative, compact, and powerful linear accelerator component for medical applications. This has now been built and integrated by Advanced Oncotherapy into their breakthrough proton therapy system.

The constant research and development for particle accelerators sometimes also bears fruit before the actual project is realised: the technology developed within a CERN feasibility study for a possible future collider turned out to be perfectly suited for a novel medical device that would allow FLASH irradiation of tumours with very high energy electrons. CERN, the Lausanne University Hospital (CHUV), and THERYQ, a medical technology company, are working together to build this device within a few years.

Progress in cancer and life sciences research is crucially supported by the capability to realistically model complex mechanisms, such as tumour growth. CERN's computing expertise and Newcastle University's experience in the simulation of brain cancer growth have resulted in an open-source, modular, and high-performance platform that enables researchers to perform and validate simulations at unprecedented scale and complexity. The platform, now managed by an international, multidisciplinary collaboration, is being successfully used in oncology, neuroscience, epidemiology, finance, and social sciences.

Technologies for healthcare innovation



Ever since Wilhelm Conrad Röntgen's accidental discovery of X-rays in 1895, physics and medicine have gone hand in hand, and advances made to particle detectors at CERN and elsewhere have continuously fuelled new developments in medical imaging.

Technologies to raise the game in medical imaging

You are likely familiar with the black and white anatomical images from medical radiography or computed tomography (CT), which enable doctors and clinicians to diagnose and monitor diseases ranging from bone fractures to cancer.

These images are obtained by measuring how much of the X-rays that are directed at a patient are attenuated or stopped when going through the body, but there is no detailed information on what happens at different wavelengths.

Indeed, much like the colour spectrum of visible light, X-rays are composed of a range of wavelengths, and these are attenuated differently by diverse materials, even of identical density. By capturing these data, it is possible to discriminate substances that would look very much alike in black and white images, and thus provide additional insights on what is happening in the body: this is called spectral X-ray imaging.

Pioneering detector technology developed at CERN by the Medipix collaborations has proved instrumental for the development of spectral X-ray imaging, with the bonus of providing an extremely high spatial resolution.

MARS Bioimaging has embedded the Medipix3 chip in its CT scanners, producing high-definition colour X-ray images that carry significantly more information compared to conventional ones. After the commercialisation of a scanner for preclinical studies, the company's focus now is a compact device for imaging the human body's upper extremities.

Currently undergoing clinical evaluation in hospitals, this innovative scanner is small enough to fit into point-of-care settings such as community clinics or emergency wards, thus bringing state-of-the-art imaging closer to the patient. It also improves the image contrast in soft tissues, in some cases eliminating the need for expensive magnetic resonance imaging (MRI).

Machine learning and artificial intelligence have the potential to be game-changers for the world of medical imaging, for example by providing support to healthcare practitioners in clinical decision-making.

Cross-fertilisation is highly beneficial: algorithms used to detect anomalies in the welds of the Large Hadron Collider have already been adapted to spot human brain pathologies from MRI scans and can be applied to other challenges. Taking these capabilities further, CERN experts have developed a platform that allows hospitals and other institutes to work collaboratively on refining machine learning algorithms without exchanging any confdential data.

Georges Charpak, a physicist of outstanding creativity, invented a Nobel-prize-winning particle detector at CERN in 1968. This novel technology had the ability to record millions of particle tracks per second, opening a new era for particle physics but also for medical imaging, where its sensitivity promised to reduce radiation doses during radiology procedures.

Technologies for healthcare innovation

Novel pathways for nuclear medicine

Nuclear medicine uses small amounts of substances called radioisotopes: these are unstable forms of chemical elements, which emit radiation as they decay into a more stable state. Specific radioisotopes are administered to the patient, generally as part of a radiopharmaceutical compound, to help diagnose and treat cancers and other diseases.

The medical community is always on the lookout for novel radioisotopes with the right characteristics to provide unprecedented treatment or diagnosis solutions. Since 2017, the CERN-MEDICIS infrastructure has been producing innovative radioisotopes specifically for medical applications and providing them to medical doctors and researchers who can assess their suitability for advanced treatments and imaging.

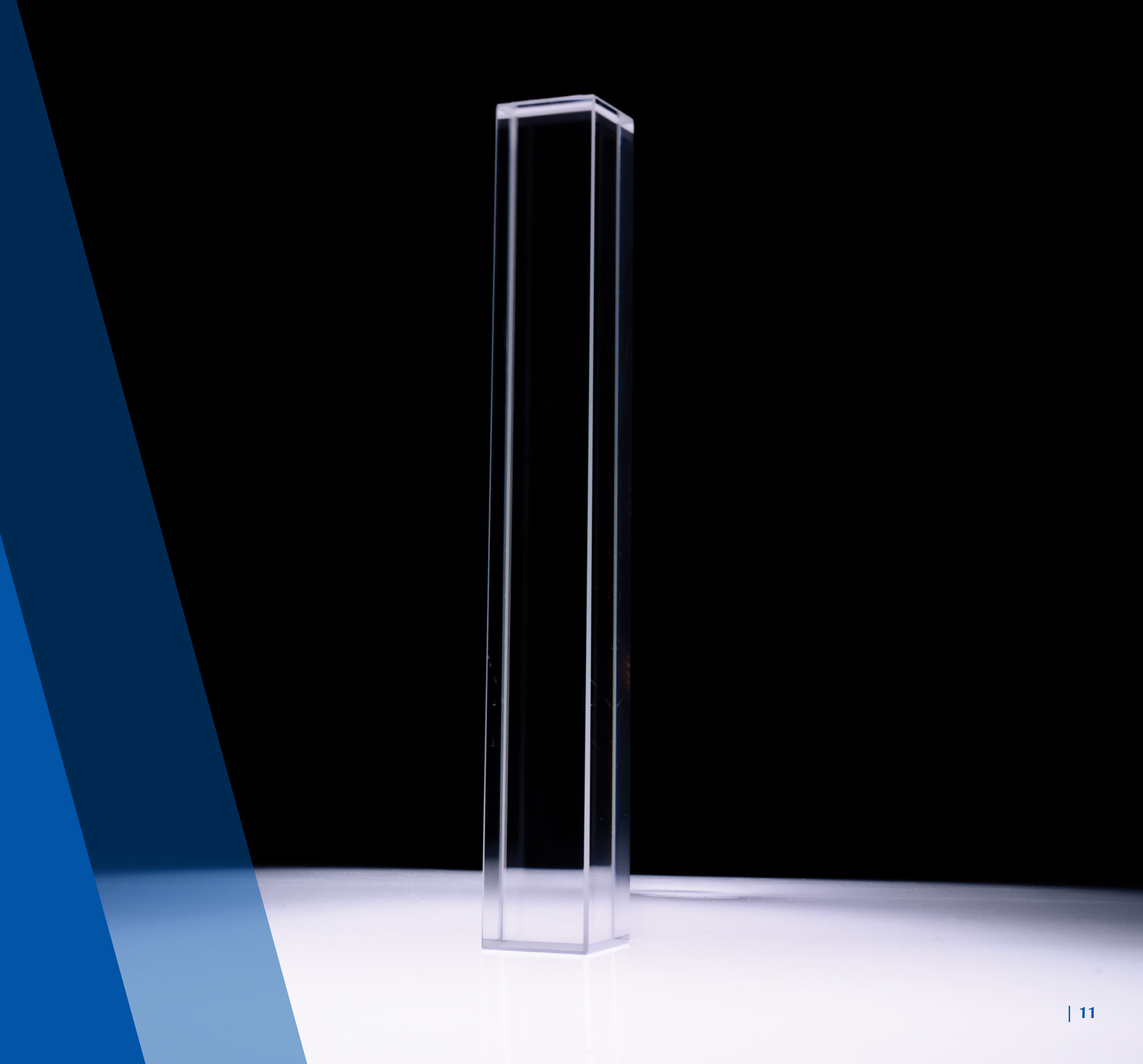
Some of these radioisotopes are uniquely produced at CERN and, thanks to the collaboration with leading European scientific institutions, an advanced pipeline of medical radioisotopes is being created for the future – improving those in use already and bringing entirely new ones to the fore.

Researchers at CERN are also exploring new ways to utilise radioisotopes to develop transportable and extremely sensitive nuclear magnetic resonance (NMR) techniques. NMR is already widely used in biochemistry, and these novel developments are finding applications in magnetic resonance imaging.

Positron emission tomography (PET) is a long-established nuclear medical imaging technique that is typically used to assess the spread of tumours. PET scanners detect specific particles – photons – emitted by the positron from the radioisotope decay.

In the 1970s, PET scanners were in their infancy. At CERN, physicists David Townsend and Alan Jeavons, with the support of radiobiologist Marilena Streit-Bianchi, used a novel image reconstruction software and an evolution of Charpak's particle detector to generate some of the first PET images, most famously of a mouse.

Modern PET scanners use photon detectors based on scintillating crystals, which are also used in many particle-physics experiments. CERN has long contributed to advances in this technology and is now supporting the development of scintillation detectors that will enhance the precision of PET imaging without increasing the radioactive dose to the patient, or reduce the dose without affecting the image quality.



Technologies for environmental protection

Extreme technologies for the aeroplanes of the future

The progress in transport has shaped the world we know today, but it has become urgent to develop cleaner and more efficient mobility solutions. Two promising technological areas to accelerate this transformation are superconductivity and cryogenics.

Superconductor materials have no electrical resistance at extremely low temperatures, enabling high currents to flow without losses. Cryogenic infrastructures maintain the very cold temperatures needed by superconductivity.

CERN's expertise in these two technologies stems from the exacting needs of the Large Hadron Collider (LHC): in its most powerful electromagnets, superconductors are cooled at a temperature of -271°C, and high currents generate a magnetic field 100,000 times more powerful than the Earth's.

CERN and Airbus UpNext are collaborating to assess the feasibility of using superconducting technologies in the electrical distribution systems of future hybrid and electric propulsion planes.

As superconducting links can carry far stronger electrical currents than traditional copper cables, they could drastically reduce the weight of next-generation aircraft and increase their efficiency.

CERN has also developed a technology to enable material tests at extremely low temperatures, which is now used by Applus+ Laboratories in a novel system that performs mechanical tests on composite materials. This is of potential interest for liquid hydrogen storage on aircraft.

Hydrogen is a particularly compelling fuel source as it generates no greenhouse gas emissions and allows huge energy storage. However, it will most likely have to be stored in its – higher density – liquid form which requires cooling at cryogenic temperatures below -253°C and poses stringent requirements on the materials of the on-board tanks. The tests on the materials of the tanks, mentioned above, will help choose the right components that can make hydrogen-powered aircraft a reality.

Scientists in academia and industry are working on more sustainable energy sources that will lessen our dependence on fossil fuels. The development of more efficient energy transmission technology will accelerate the transition to renewable energy. The aeronautical sector is seeking ways to reduce its carbon emissions. These are just a few examples of global environmental challenges that can benefit from the disruptive technologies developed at CERN.

Supporting the quest for alternative energy sources

In the search for sustainable energy sources, some scientists are attempting to replicate the fusion reaction that takes place in the core of the Sun.

ITER, which is poised to be the world's biggest fusion experiment, and the LHC both need superconducting magnets, cryogenics, vacuum systems, all at very large scale and in challenging radiation environments: this has naturally led to many collaborations between CERN and the ITER Organization.

Innovative and demanding magnet systems are one of the technological challenges in this field and also in the pursuit of much more compact fusion reactors. CERN shared its software expertise with Tokamak Energy, to help them simulate currents and magnetic fields in their magnet concept.

A successful transition to renewable energy sources requires cutting-edge grid technologies capable of efficiently transmitting large quantities of power. Traditional methods, such as overhead lines and conventional underground cables, are facing significant challenges in accommodating the increasing power demands.

In this regard, the application of superconducting technologies emerges as a promising solution. CERN and SuperNode are developing a novel type of insulation for superconducting cables that would allow them to be integrated in submarine and terrestrial electrical grids.

Technologies for more sustainable lives

Algorithm optimisation for longer battery life

We are now used to our phones acting on voice command, and interactive capabilities are becoming common in household appliances. As our devices become smarter, integrating more sensors and artificial intelligence (AI) capabilities, their power consumption increases: how long a battery lasts between charges is an important parameter when choosing our next smart object. Deploying the AI applications on the devices (Edge AI) and removing calculation steps without affecting the accuracy (pruning) are two approaches to energy-efficient technology.

Physicists working on the Large Hadron Collider (LHC) experiments have become skilled in using pruning techniques. Particle collisions in the LHC generate huge amounts of data, of the order of 40 TeraBytes per second, that cannot possibly be stored for later processing. Dedicated algorithms must quickly and efficiently select the most interesting collisions, and pruning can make the process leaner.

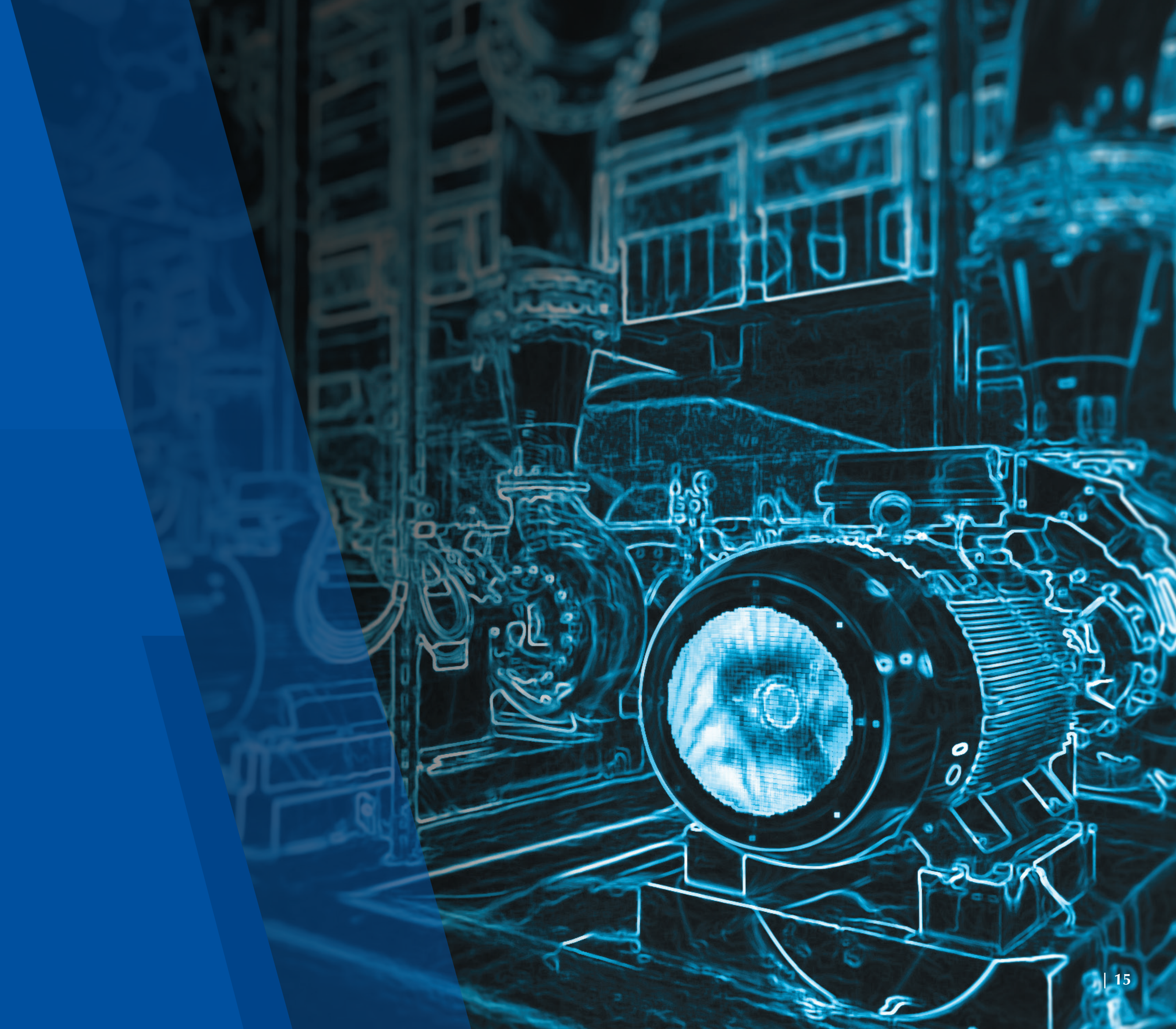
CERN and CEVA, a company licensing wireless and sensor technologies, are collaborating to test a combination of algorithm optimisation and of hardware implementation to make the algorithmic process more efficient and reduce power consumption at the same time.

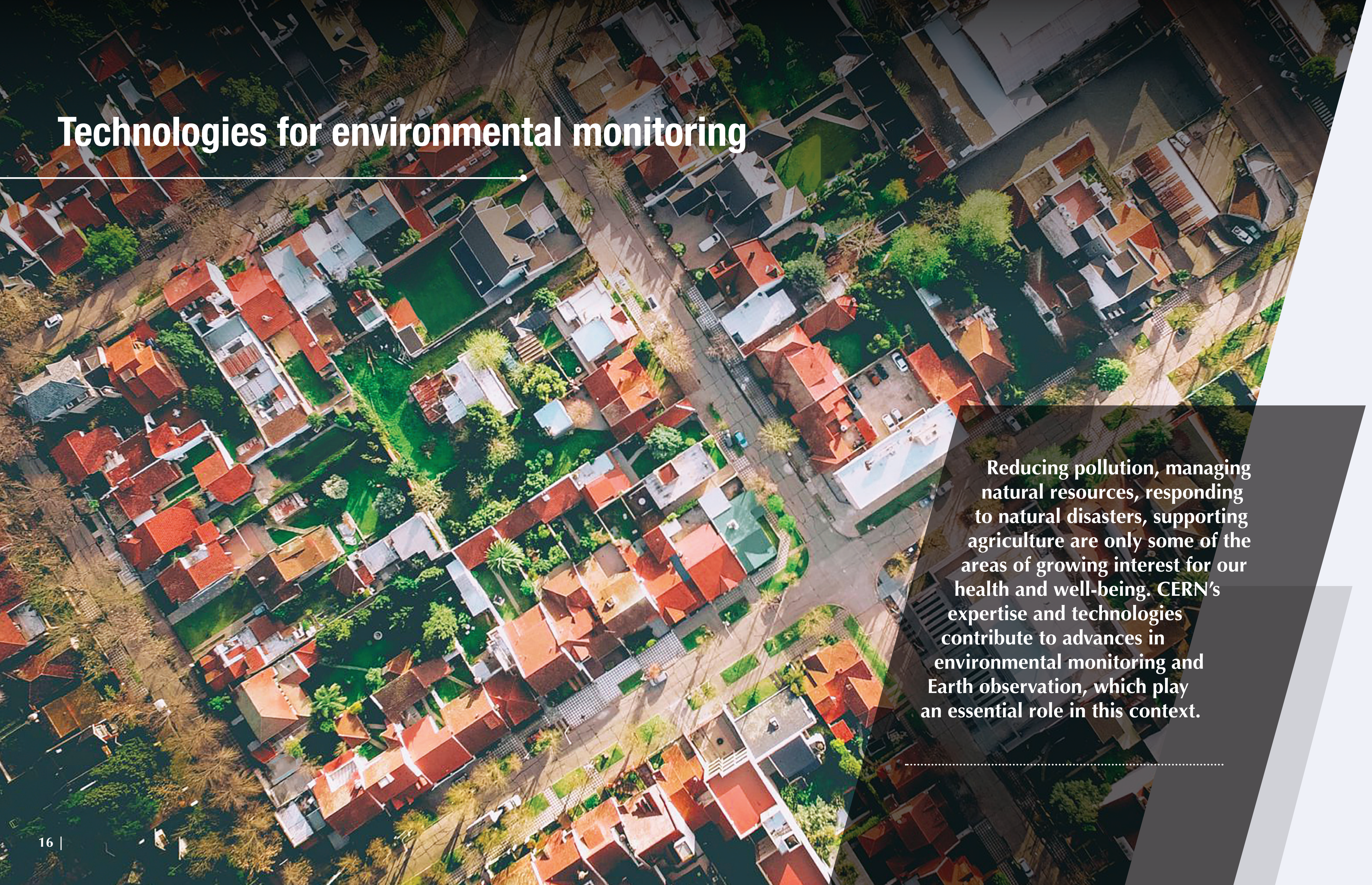
A digital twin to reduce energy consumption

Finding appropriate solutions to lower the energy consumption of industries and large-scale research facilities is key to a more sustainable world.

Across the vast CERN site, many auxiliary systems and services contribute to the energy usage of the Laboratory. Through an innovation partnership with ABB Motion, a global technology leader in supplying world-class drives and motors, CERN's cooling and ventilation infrastructure will be a test ground for energy saving measures.

Smart sensors will transform traditional motors, pumps, mounted bearings and gearing into wirelessly connected devices, whose data will be used to develop digital twins – virtual representations – of the cooling and ventilation systems. These data insights, paired with expert analysis, will allow for the simulation and testing of energy reduction scenarios, and the most efficient ones will be implemented. The outcomes and successful methods from this collaboration will be publicly shared, allowing other large facilities such as laboratories or industrial sites to learn best practices and potentially implement energy efficient large-scale cooling and ventilation systems.





Technologies for environmental monitoring

Reducing pollution, managing natural resources, responding to natural disasters, supporting agriculture are only some of the areas of growing interest for our health and well-being. CERN's expertise and technologies contribute to advances in environmental monitoring and Earth observation, which play an essential role in this context.

Solutions for a healthier planet

Air pollution is a critical global health issue, responsible for an estimated 11% of all deaths worldwide. To address this and other environmental concerns, it is essential to monitor air quality across large areas and gather information about our planet using remote sensing technologies. These efforts are key to understanding, managing, and protecting the environment, as well as supporting sustainable development and ensuring our health and well-being. CERN's diverse expertise, from radiation safety to quantum computing technologies and monitoring software, contributes to the advancement of techniques for environmental monitoring and Earth observation from satellites.

As part of their long-standing partnership, the European Space Agency (ESA) and CERN are currently investigating the potential of quantum machine learning for analysing Earth Observation data. Quantum technology represents a groundbreaking approach for addressing complex problems that lie beyond the capabilities of classical computing methods. Innovation in these cutting-edge fields has the potential to transform both science and society, and CERN is actively driving it through its Quantum Technology Initiative.

The CERN spin-off company PlanetWatch has developed an infrastructure capable of receiving and validating high-frequency data streams from thousands of sensors across the globe. This enables a more comprehensive understanding of the impact of air pollution, which in turn helps us take more effective action to reduce it.

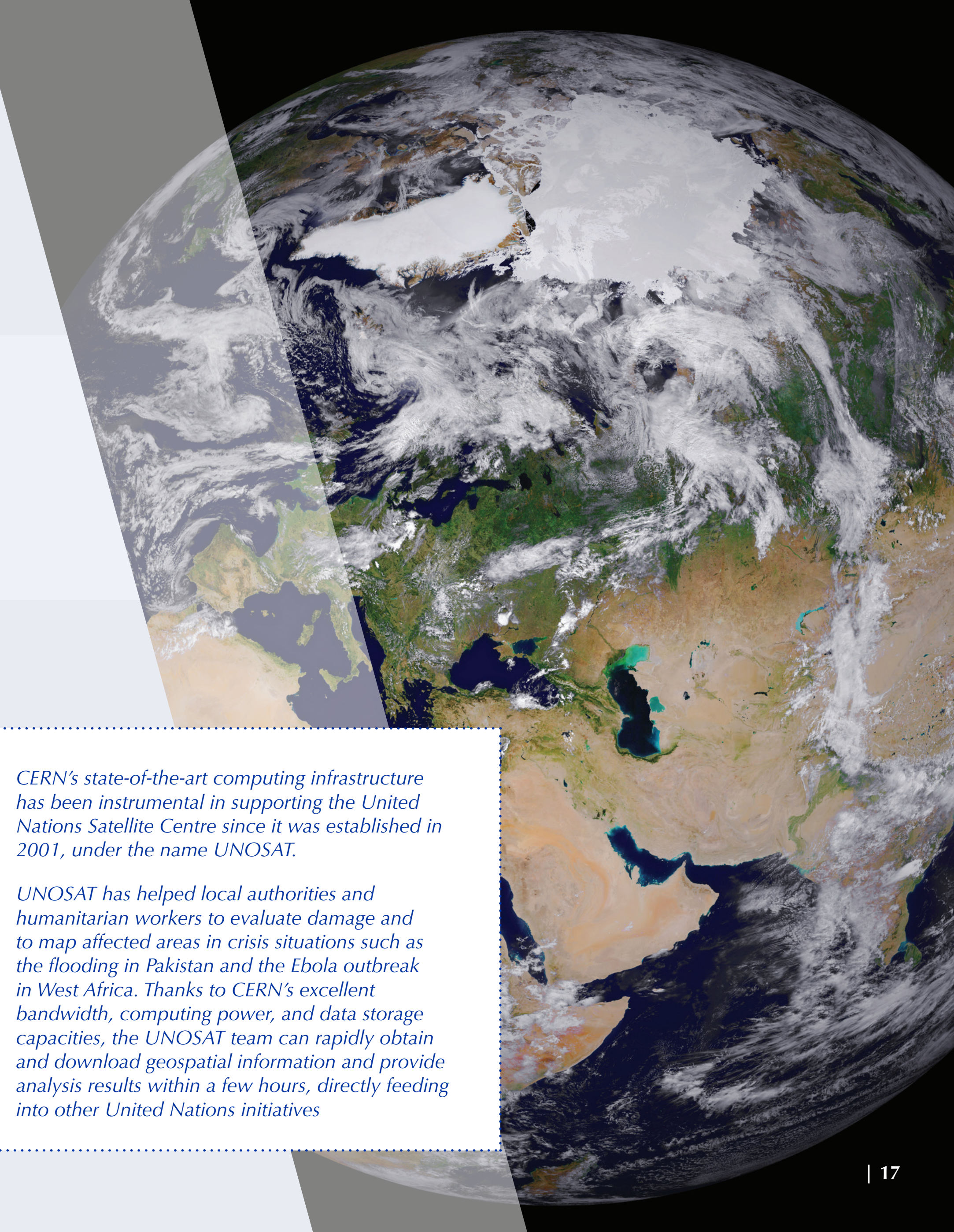
BAQ, another spin-off company of CERN, is aiming at reducing our exposure to radon, a natural radioactive gas that is the second leading cause of lung cancer after smoking. BAQ is deploying an innovative radon dose monitor developed by CERN, together with a cutting-edge cloud-based service for data collection and analysis. By leveraging real-time data, this technology can drive the implementation of targeted mitigation measures to protect individuals from radon's harmful effects.

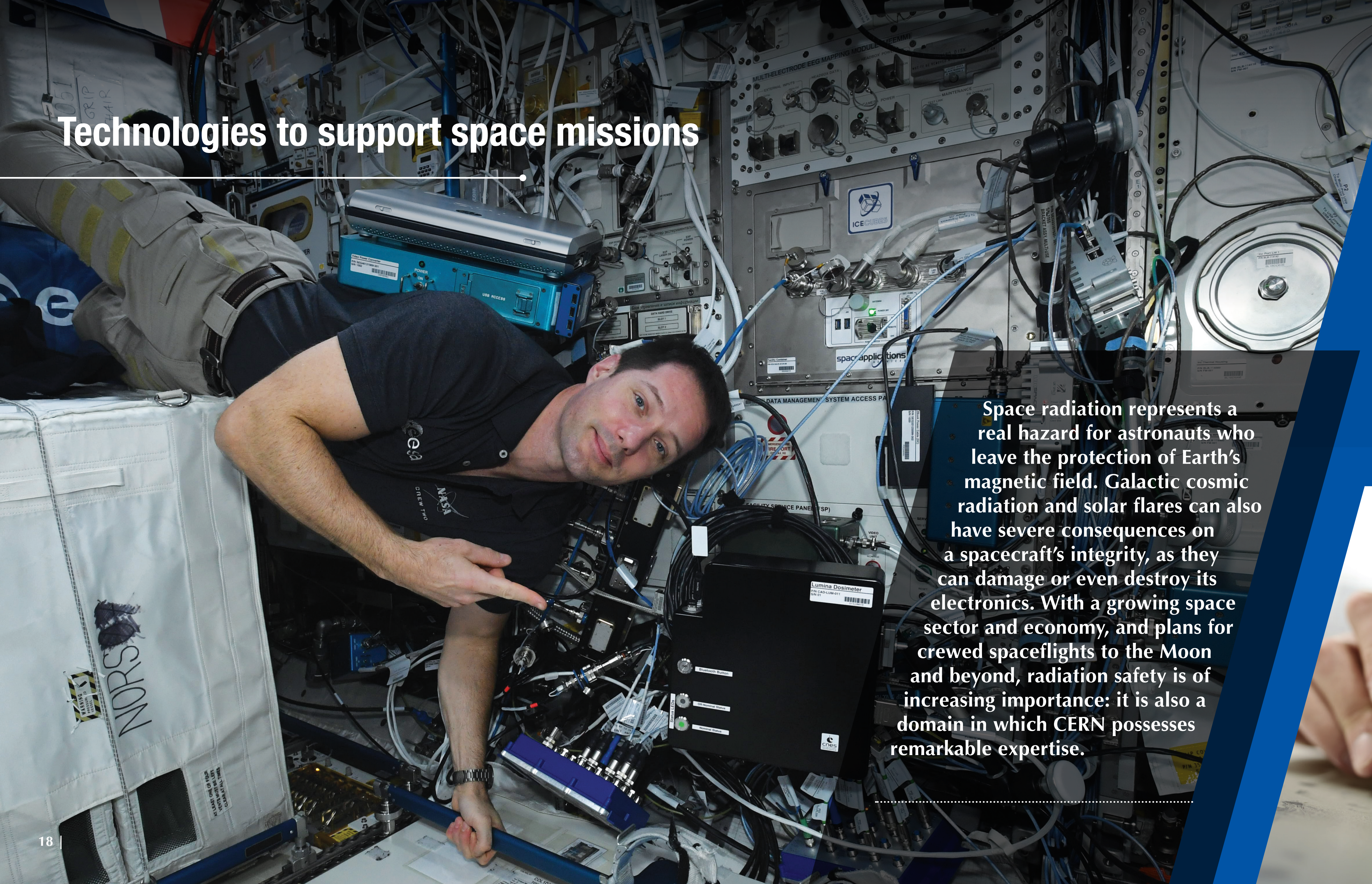
Powering satellite mapping for humanitarian efforts

As extreme weather events become less predictable, the need for satellite images of the Earth from space is increasingly important in emergency situations. Satellites provide vital information on the lay of the land and efficient routes for rescue teams during catastrophes like floods, earthquakes, and forest fires. Satellite mapping also plays a crucial role in maintaining peace, enabling a more comprehensive assessment of the situation through monitoring population movements, monitoring borders, and assessing damage.

CERN's state-of-the-art computing infrastructure has been instrumental in supporting the United Nations Satellite Centre since it was established in 2001, under the name UNOSAT.

UNOSAT has helped local authorities and humanitarian workers to evaluate damage and to map affected areas in crisis situations such as the flooding in Pakistan and the Ebola outbreak in West Africa. Thanks to CERN's excellent bandwidth, computing power, and data storage capacities, the UNOSAT team can rapidly obtain and download geospatial information and provide analysis results within a few hours, directly feeding into other United Nations initiatives



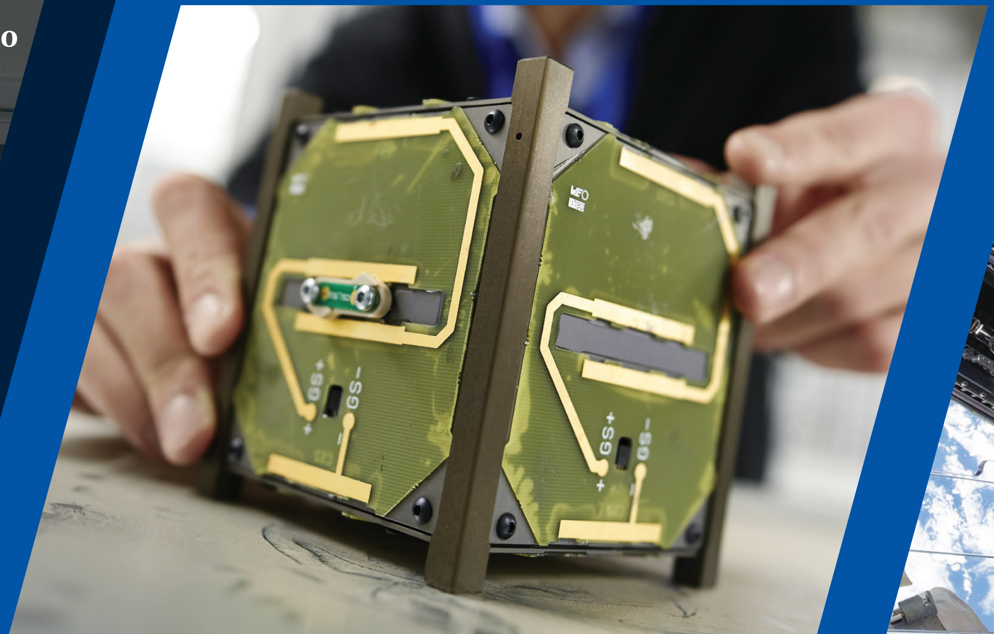


Technologies to support space missions

Space radiation represents a real hazard for astronauts who leave the protection of Earth's magnetic field. Galactic cosmic radiation and solar flares can also have severe consequences on a spacecraft's integrity, as they can damage or even destroy its electronics. With a growing space sector and economy, and plans for crewed spaceflights to the Moon and beyond, radiation safety is of increasing importance: it is also a domain in which CERN possesses remarkable expertise.

Predicting radiation damage for more reliable spacecraft

In space, as in the Large Hadron Collider (LHC), radiation can damage electronic components and cause malfunctions. CERN has developed a device to measure complex radiation fields and their impact on electronics within the challenging radiation environment of the LHC. To determine its suitability for space applications, a miniature version of the device was installed on board the CELESTA microsatellite, the result of CERN's partnership with the University of Montpellier. In July 2022, the European Space Agency (ESA) sent the satellite into a 6,000 km orbit around Earth. Prior to the mission, a model of the microsatellite was tested at a one-of-a-kind CERN installation, originally designed for radiation testing of CERN's electronic equipment. Data from CELESTA indicate that the installation can indeed replicate the low-Earth orbit radiation environment, making it suitable for testing components and systems intended for space applications. In fact, CERN possesses several unique facilities that can reproduce the most extreme radiation or thermal conditions in space. Critical components of ESA's Jupiter Icy Moons Explorer (Juice), launched in 2023, were tested at CERN, in the only installation on Earth capable of replicating Jupiter's harsh radiative environment. These tests helped optimise the spacecraft's design.



Assessing radiation exposure to protect space crews

The potential impact of space radiation is a critical hazard for crewed missions to the Moon and beyond. Since 2012, NASA has been developing systems based on the CERN-born Timepix detectors to monitor the radiation environment on the International Space Station and to support various missions. In 2022, the Timepix detectors ventured around the moon as part of the first flight in NASA's new lunar exploration programme and are now heading into deep space onboard an astrobiology mission aimed at studying the impact of radiation on living cells.

In 2021, an experiment using active dosimeters made of two several-kilometre-long optical fibres was activated on the International Space Station by ESA astronaut Thomas Pesquet to determine the amount of radiation that astronauts and electronics are exposed to. Irradiation tests were part of CERN's contribution to this dosimetry experiment developed under the coordination of the French Space Agency, CNES, and with the involvement of the Laboratoire Hubert Curien at the Université Jean-Monnet-Saint-Étienne and iXblue.

Technologies keeping us safe

Quantum physics to prevent identity theft

The security of personal identification documents, such as passports and drivers' licences, is essential both online and in the real world. Cryptography, the art of using codes to keep information secure, is a useful tool to prevent identity theft, but it must continuously evolve to stay ahead of potential threats.

The future of secure identity management and cryptography might lie in quantum physics phenomena: for example, particles can remain entangled even when they are vast distances away.

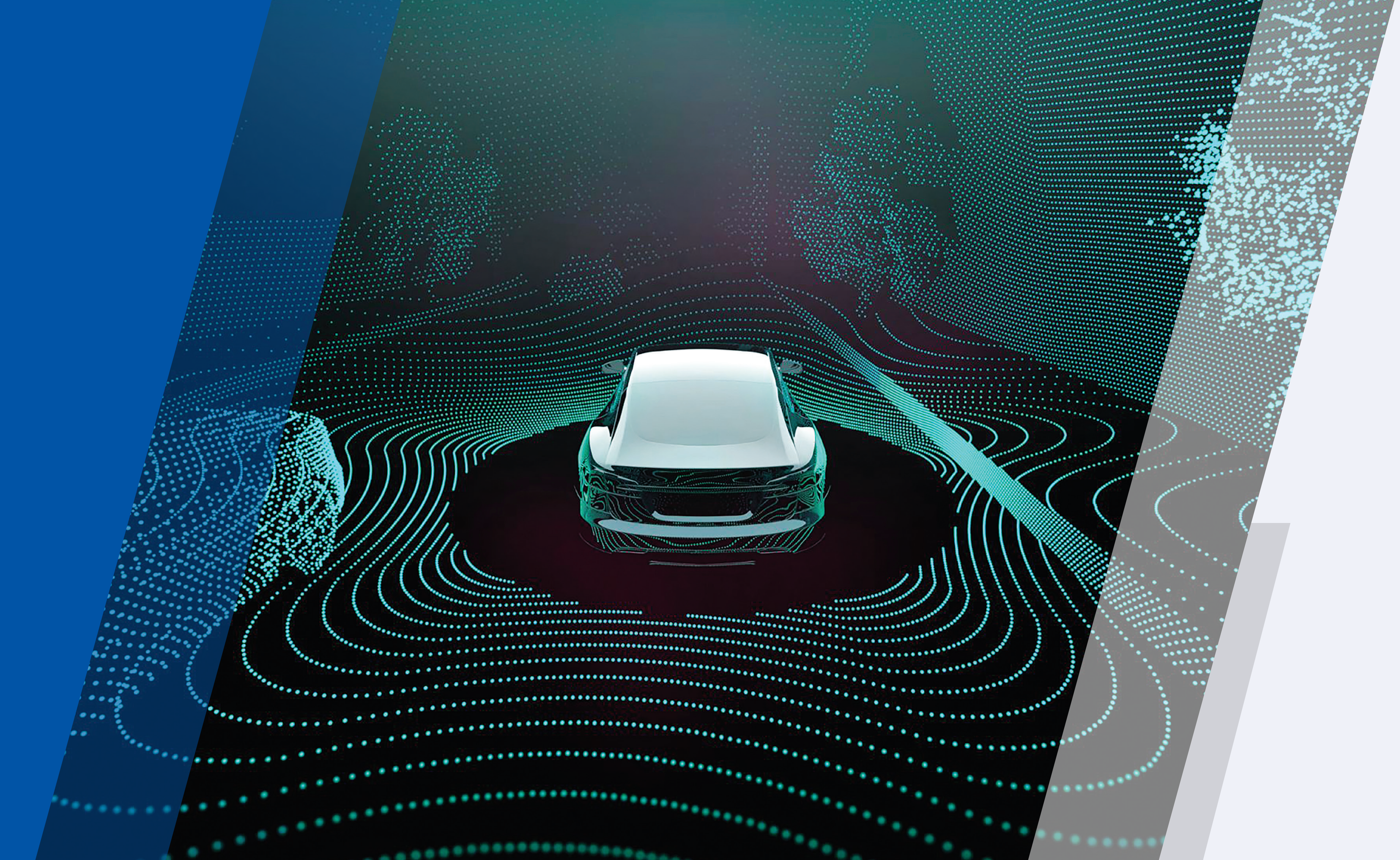
Cryptographers and mathematicians from the Bundesdruckerei Group (BDR), which develops secure identity solutions, are collaborating with physicists, material experts, and antimatter scientists from CERN to identify cryptography techniques that will keep information secure in 10 or 20 years from now. One day, cryptographic keys could be generated by methods based on the principle of quantum entanglement.

Improved data science for better market surveillance

The days of financial traders jostling on the trading room floor with phones in hand are over: today, they use algorithms and machine learning systems that can react faster and anticipate fluctuations more accurately than humans.

As the technology has become more sophisticated, so has the manipulation of it. Fraud or malpractice are increasingly difficult to detect at the scale of the high-speed transactions on commodity futures markets, in which multiple orders per nanosecond are placed.

Financial detectives look for anomalies in the transactions, as these might be signalling fraud. Similarly, physicists search for "unusual" particle collisions among the one billion per second generated by the Large Hadron Collider (LHC). CERN, the Commodity Risk Management Expertise Center (CORMEC), and Wageningen University & Research are jointly creating new methods to enable governments and financial regulators to spot irregularities in an ever-more complex landscape, thus contributing to protect the integrity of the financial markets.



Reducing the risk of impact for safer autonomous navigation

Autonomous or self-driving cars require elaborate algorithms to manage and process the data from the numerous sensors on the vehicle. These algorithms must think quickly, take the right decisions, and correctly interpret the vehicle's surroundings.

To handle the billions of collisions per second in the LHC detectors, scientists at CERN also require decision-making systems that act fast, while retaining accuracy.

CERN and car-safety company Zenseact teamed up to develop computer vision technologies, which help the car make sense of data and respond to its external environment. The collaboration has shown that it is possible to pack significantly more functionalities into specialised electronics, resulting in high accuracy and short latency even with limited computational resources.

These findings can also be applied to other domains confronted with similar demands, such as portable devices, satellites, and drones.

Intelligent robots working in harsh settings, in industry as well as in the LHC tunnels, also face the challenge of automated navigation, but in complex and cluttered indoor environments. CERN tackled the problem together with the start-up Terabee, which develops advanced sensing solutions.

The collaboration allowed Terabee to develop a fast, small, lightweight, and eye-safe distance measurement sensor ideal for fast moving robots (including drones) and for many industrial automation and smart buildings applications. The same sensor technology now powers Terabee's anonymous, privacy-compliant people counters, which enable building managers to reduce energy consumption and expenditure based on real-time occupancy levels.

Technologies of the future to preserve our past

To understand, authenticate and preserve great works of art, we must study them in minute detail. However, it is critical that the techniques used do not damage them. Several non-destructive processes for the inspection of artworks involve the use of particle beams: they are therefore a natural playground for the application of CERN technologies.

Particle detectors and accelerators to examine artworks

X-ray imaging is a well-established analysis technique. Detectors developed at CERN by the Medipix collaborations offer extremely high resolution coupled with the capability of measuring the attenuation of X-rays at different wavelengths of their spectrum, when passing through the object to be examined. This so-called spectral X-ray imaging is a game-changer in the medical field but also in the art world.

The start-up InsightART embedded these detectors in their X-ray devices that quickly scan large art objects and determine which pigments were used in a painting – all without causing any damage to the priceless piece under examination. The key information provided by InsightART is one of the elements that allowed a group of experts to confirm that the painting The Madonna and Child should indeed be attributed to Raphael.

Non-destructive analysis of artworks is also performed using beams of ions, such as protons and helium, which are typically produced by bulky accelerators. Moving fragile and precious objects or frescoes, even over short distances, to the analysis site is challenging and sometimes impossible due to logistical, economic, and safety concerns.

CERN and the Italian National Institute for Nuclear Physics (INFN) have built MACHINA, a compact and portable accelerator for cultural heritage applications based on CERN's linear accelerator for medical applications.

In 2022, MACHINA was intensively tested, satisfying all the initial requirements, and will soon be operational at the INFN Laboratory of nuclear techniques for Environment and Cultural Heritage (LABEC) for the first test measurement campaigns. The accelerator will then be transferred to the renowned centre for art conservation Opificio delle Pietre Dure in Florence, to analyse a variety of objects too fragile or too large to be moved. MACHINA's portability will enable it to be transported to other museums or conservation sites for in situ measurements.

Open-source technologies for global challenges

Digital libraries and repositories to support knowledge sharing

For ideas and new innovations to flourish it is essential to have access to the ideas that came before. With more and more information at our fingertips, however, it is becoming hard to manage, access, and use all these data: digital libraries and repositories today are complex systems that are essential to support research, communication, and collaboration worldwide.

CERN has developed its own flexible, high-performance, open-source digital library framework. This technology is the backbone of the products and services developed by the CERN spin-off TIND: these are now used by libraries, universities, and global institutions to acquire, archive, manage and share information.

CERN also maintains the world's largest general-purpose research repository, based on the same digital library framework. This easy-to-use repository enables scientists from any field to preserve and share their research outputs.

CERN's spin-off Orvium uses the repository to store data for its innovative open-access scientific publishing platform. The company is revolutionising academic paper review and publishing, by making these processes more transparent and open.

Modelling airborne pathogen risks for safer indoor spaces

Since the onset of the COVID-19 pandemic, space managers around the world have been confronted with the need to establish guidelines for the use of workspaces and meeting rooms.

CERN has responded to the challenge by developing an open-source tool to model virus concentration in enclosed spaces with varying parameters, such as room size, time spent in the room, mask-wearing, number of people, and ventilation. Collaboration with health experts allows the model to be regularly refined, validated against clinical data, and expanded to include other airborne pathogens.

The tool features a user-friendly interface that enables space managers and safety officers to readily assess the risk level associated with the existing safety measures and has been rapidly adopted by international organisations, universities, schools, and individuals. The World Health Organisation (WHO) is now collaborating with CERN to define and develop a standardised algorithm to quantify airborne transmission risk indoors.

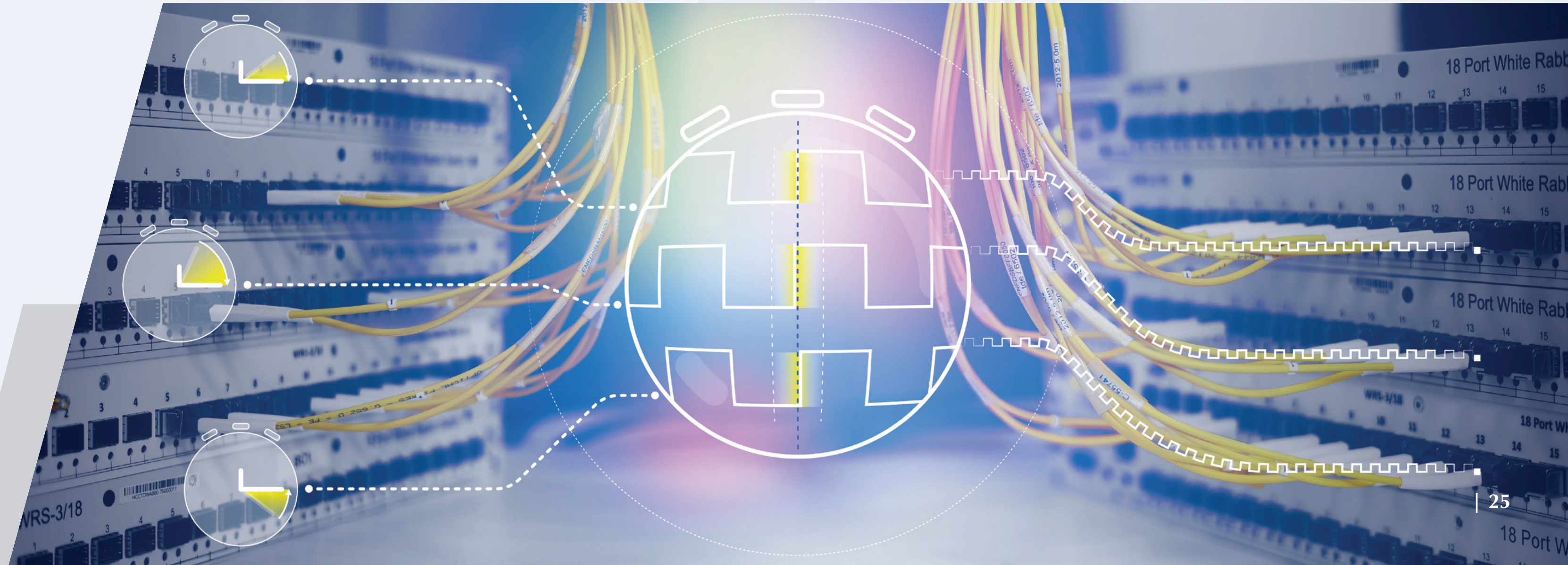
Robust sub-nanosecond synchronisation when timing is of the essence

Telecommunications, financial markets, and quantum networks are just some of the applications that need increasingly precise and accurate time synchronisation and reliable data delivery. Furthermore, terrestrial fibre-based time distribution is becoming increasingly important to reduce our overreliance on satellite-based synchronisation.

The exacting requirements of CERN's accelerator complex have led to the development of a novel time-synchronisation system that offers sub-nanosecond accuracy and precision of a few picoseconds. The technology's hardware, firmware, and software are fully open. The hardware is available through the CERN Open Hardware Licence, developed by the Laboratory as a tool to promote collaboration.

This CERN-born time-synchronisation system is widely used in scientific facilities and has been incorporated in a worldwide standard of the Institute of Electrical and Electronics Engineers (IEEE) in 2020, making it easier for industry to adopt it.

For instance, in the financial markets, precise timestamping ensures fairness and transparency. Deutsche Börse is using the CERN-developed protocol in their trading system infrastructure to synchronise network devices and timestamp transactions at nanosecond level.



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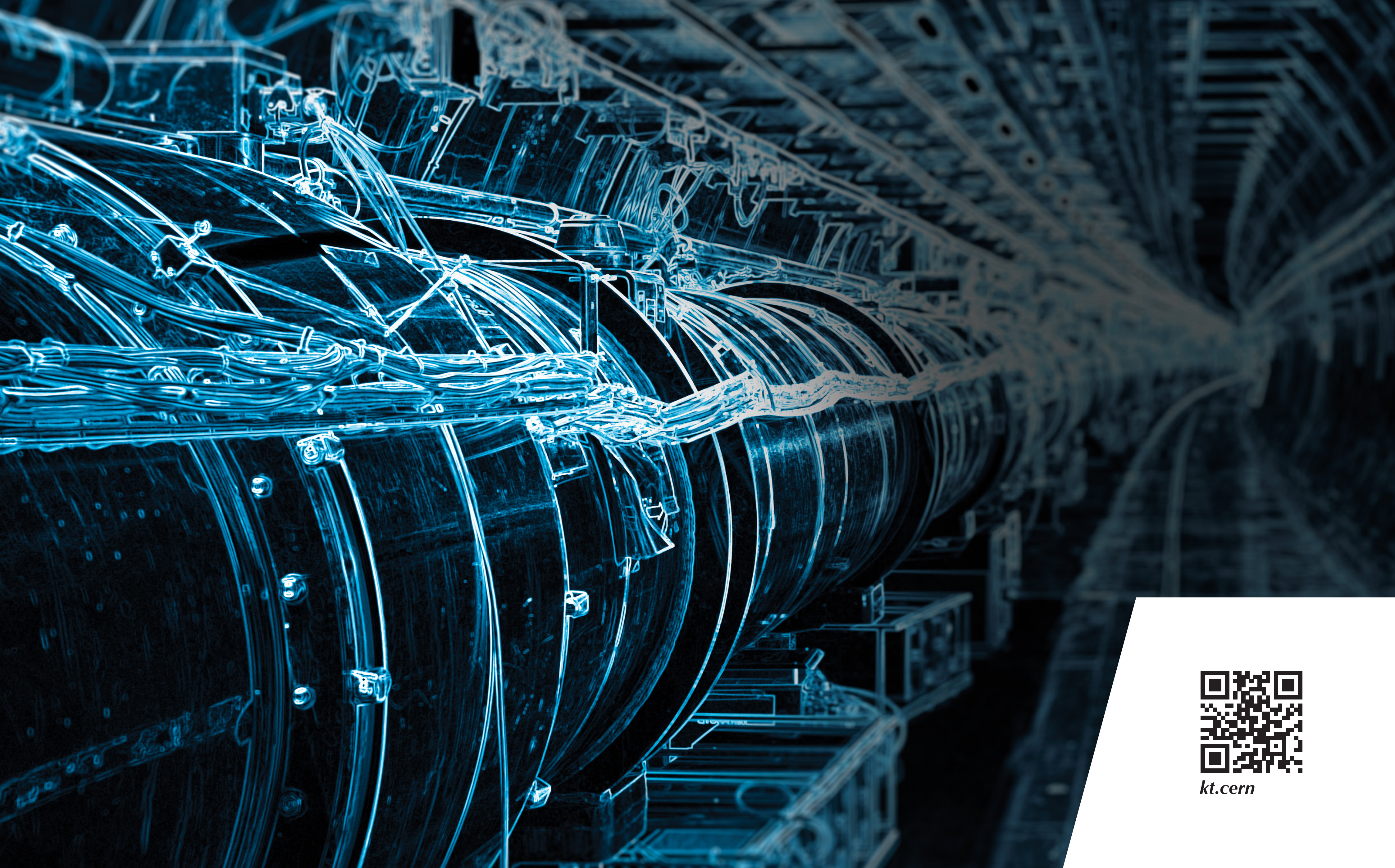

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