highlights

2017

SCK•CEN

STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

“ In tune
with society ”

According to our mission SCK•CEN works on issues that are important to society, today and in the future: safety and efficiency of nuclear installations, solutions for the disposal of radioactive waste, protection of mankind and the environment against ionizing radiation, and sustainable development. In this way we contribute to a viable society, for ourselves and for the generations te come.

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STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

2017
Highlights

From dream to breakthrough

DEAR READER,

A small lump in the neck, nothing more. Cancer, according to the diagnosis. More than 65,000 Belgians are diagnosed with cancer every year. This figure is expected to increase to 80,000 by 2025. This means that an average of 200 people will be receiving bad news every day. The chances of survival are increasing year by year thanks to new and improved treatments, but the same cannot be said for quality of life. Patients often have to battle adverse effects for years after treatment has been concluded and, as a result, they sometimes feel that their work and social life is impaired. Personalised and, more importantly, less-invasive cancer treatments are therefore vital.

We are proud that our centre can play a role in the fight against cancer: and a crucial role at that. Our BR2 research reactor produces more than 25% of the global demand for radioisotopes every year, and even up to 65% in the event of a high level of demand. This makes it possible for around 30 million examinations to be carried out every year. In 2017, we made greater strides than ever before in the fight against cancer. Due to demands in the medical world, we adapted the radiation facilities of our BR2 research reactor further in order to produce even more different radioisotopes – in addition to molybdenum-99 (Mo-99) – and/or to increase the radiation capacity. For example, consider lutetium-177 for the treatment of prostate cancer and yttrium-90 for the treatment of liver cancer.

With our multifunctional research facility MYRRHA – and in the first instance the MINERVA accelerator and its radiation stations – we will continue to embark on a similar path in the future. We will carry out research into theranostic radioisotopes (for diagnostic research or therapeutic treatment) and produce these radioisotopes in order to destroy cancer cells in a more targeted manner. By doing so, we will be able to significantly reduce the side effects for patients.

Our international research efforts, our scientific excellence and the unique infrastructure of the study centre have not gone unnoticed. After an intensive audit, the International Atomic Energy Agency (IAEA) awarded SCK•CEN the ICERR label (International Centre Based on Research Reactors) at the General Conference in Vienna in 2017. With this recognition, the IAEA is declaring that we are a leading, internationally advanced nuclear research centre that opens its doors to all countries that are hoping to develop their nuclear science and technological programmes. SCK•CEN is the third institute in the world that has been awarded this unique label. This recognition contributes to our mission and international image.

2017 was also the year in which we set boundaries for undertaking new challenges. Radiobiologist Sarah Baatout thus braved the freezing temperatures and vicious wind in Antarctica in order to study the impact of extreme conditions on the immune system, thereby simulating the living conditions of astronauts travelling through space. What is more, we sent the very first bioreactor to the ISS in space and began the hunt for the enigmatic sterile neutrino, which can drastically change our vision of the universe.

Eric van Walle
SCK•CEN
Director-General

In summary: 2017 was a year of dreams and breakthroughs. Please feel free to browse through this annual report and relive our dreams and breakthroughs with us.

I hope you enjoy reading this!

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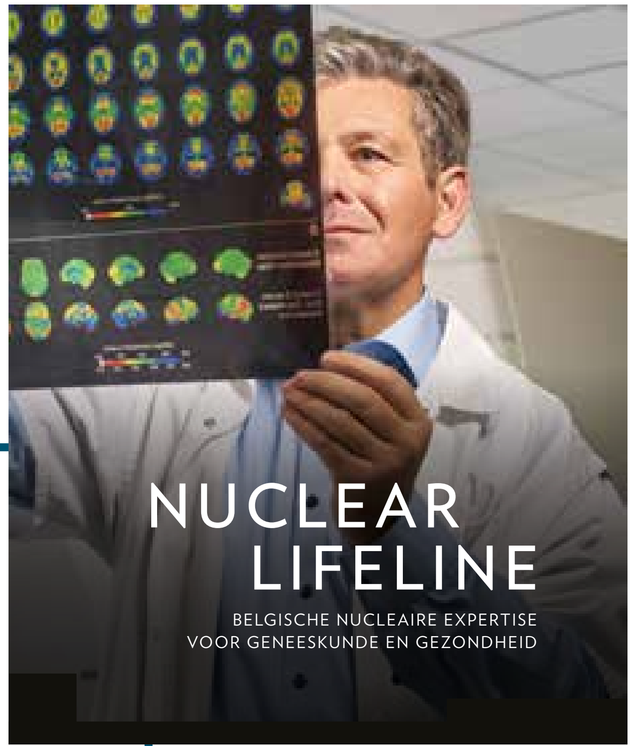

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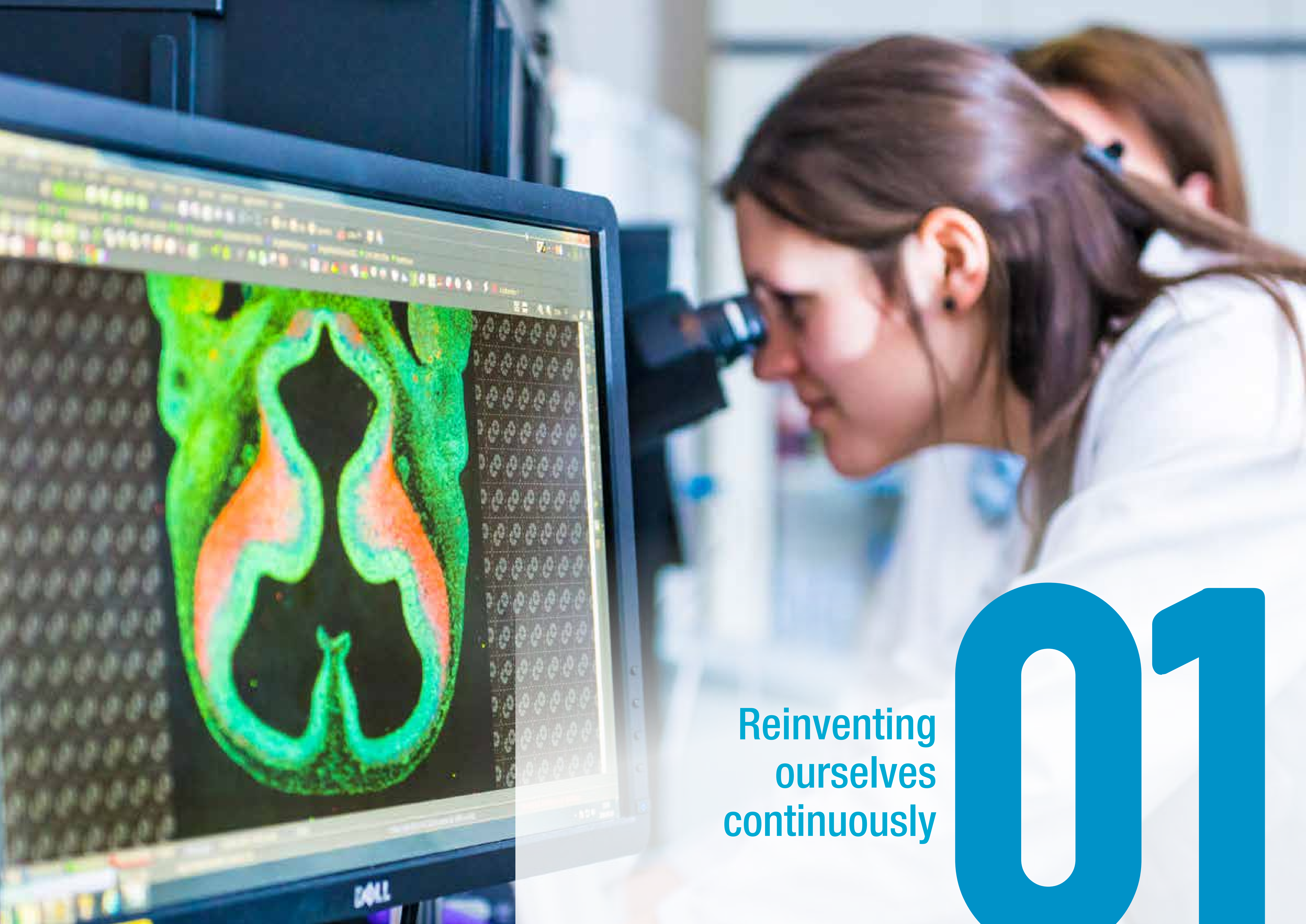


01

Reinventing ourselves continuously

Value, science and society, a winning combination for SCK•CEN

SCK•CEN has always coupled its long history of scientific excellence with a strong contribution to society. Finding a way to enhance and perpetuate its activities without betraying its DNA has now become a top priority for our institution.

Initially created to establish our nuclear expertise and to pave the way for Belgium to begin making use of nuclear energy, SCK•CEN has seen its tasks expand to incorporate an array of applications that is even broader than the ionising radiation that it handles: nuclear medicine, cutting-edge dosimetry, fundamental research and even space exploration. At the same time, the centre has also moved from being wholly funded by the State to obtaining its funding from a combination of public financing, research grants (regional, national and international) and service provision.

"European grants and funds to assist with research, for example, are an important source of funding. In this regard, the success rate of our scientists when making submissions is rather impressive: around 75% for the Horizon 2020 programmes, which is extremely high", explained Yves Boland, Business Development & Support Director at SCK•CEN. *"State funding is no longer enough for us. We need to diversify".*

Traditionally, it is the research and development teams that support business development, but at SCK•CEN, the opposite is true. *"We are the ones who support the scientists,"* continued Boland. *"We ensure that the Centre is able to continue generating resources that will enable it to perpetuate its research activities, create added value and invest in human and material resources. The number of high-level innovations that are created here makes the work extremely satisfying. In the end, the most difficult thing is deciding what you are going to focus on. Luckily, we have tools that allow us to assess the potential of the various activities within the centre".*

Opening itself up to the world

For an institution like SCK•CEN, the value of its activities lies as much in the creation of its own revenues rather as in a maximisation of its impact on society. *"If you want to bring innovation and research out of the laboratories, and if you want to have an impact on society, it is also necessary to form partnerships with the outside world, whether it be with private partners or with institutions. This is absolutely essential if you want your knowledge to be used to create new goods or services that are of use to society,"* asserted Boland.

The BR2 research reactor is a perfect example of that combination of knowledge building, applications with a strong societal focus and openness to the world. *"It is worth pointing out that the first stage in the production of a large proportion of the radioisotopes used in nuclear medicine takes place within this reactor, which was initially designed with a view to studying nuclear materials and fuels. Thanks to that, a portion of the operating expenses of the reactor is absorbed, which allows us to continue our research,"* stressed Boland. However, this materials research task still has a beneficial impact on society. *"In the wake of Fukushima, the nuclear industry realised that it was important to possess materials that are likely to buy us some time in the event of a nuclear accident. That is why there is so much interest in research reactors like the BR2, which is one of the rare examples of a reactor that enables operating conditions spanning a number of years to be simulated over a relatively short period of time".*

> *"European grants and funds to assist with research are an important source of funding. The success rate of our scientists when making submissions is rather impressive: around 75% for the Horizon 2020 programmes, which is extremely high."*

Conquering the radiopharmaceuticals market

In recent years, SCK•CEN has also developed a particular interest in the promising field of radiopharmaceuticals. This up-and-coming market, which promotes the use of radioactive isotopes for medical purposes, is currently reporting an annual turnover estimated at 1 billion euros. However, forecasts show that it could reach 14 billion euros over the next ten years. *"The industry is experiencing a paradigm shift. Radioelements are no longer purely destined for use in medical imagery. New generations of radioisotopes are now being used to fight illnesses such as cancers with excellent results. This is a major growth area for our research centre, and all the more so since certain foreign production reactors have been forced to shut down, as we are well-placed to take over their activities,"* explained Boland.

> *"The number of high-level innovations that are created here makes our work extremely satisfying. In the end, the most difficult thing is deciding what you are going to focus on."*

Decommissioning: recognised expertise

The internationally recognised expertise of SCK•CEN in the decommissioning and decontamination of nuclear facilities is also a significant source of revenue for the centre. *"SCK•CEN made history by being the first player in Europe to decommission a reactor of the same type as those used in Belgian facilities. In order to achieve this, we developed a whole range of new techniques. This expertise enables us to offer consultancy services to other operators for current or future decommissioning projects, regardless of whether they are in Germany or Belgium, for example".*

Innovation and value, hand in hand

This recognised expertise, this mastery of technology and this tradition of scientific excellence have clearly not come about by accident. They are deeply rooted in the corporate culture at the centre. Yves Boland is convinced of this. *"All of our scientists and employees are extremely motivated by their work. Many of them have been able to maintain a strong link with the academic world and the world of fundamental research. It is important to preserve that attitude. It would not be healthy to focus all of our energy on the valorisation of our activities. We have missions to fulfil for the society; this is what makes the centre truly one of a kind".*

SCK•CEN – ANMI: a partnership with high added medical value

The recent partnership entered into with the promising Liège start-up, ANMI, reaffirms SCK•CEN's presence in the field of medical applications, particularly in the area of nuclear medicine, in which the diagnostic and therapeutic potential is increasing rapidly.

We are on the verge of a medical breakthrough in the field of nuclear medicine. Historically dominated by diagnostic applications, the radiopharmaceutical compounds market is now achieving significant advances, particularly in the field of targeted cancer therapy, which has seen some spectacular results. Those new treatments not only require diagnostic and therapy (theranostic) tools that are affordable and simple to use, but must also be sufficiently advanced to meet the expectations that they raise.

An innovative "theranostic" kit

That is what the partnership between SCK•CEN and ANMI (Advanced Nuclear Medicine Ingredients) is all about. This young and promising Belgian start-up, based in Liège, offers radiopharmaceutical and radiolabelled precursors. It stages itself as a global supplier of services in the field of nuclear medicine. *"Most notably, it has developed an innovative technology for diagnosing prostate cancer, for which it is in the process of obtaining the approvals necessary to enable it to be used on a large scale,"* revealed Yves Boland, Business Development & Support Director at SCK•CEN. The real masterstroke by ANMI is its successful development of a kit combining a radioactive charge with a biological vector that specifically targets cancerous cells within the prostate. As an added bonus, not only can this vector be used for diagnosis, it will also be possible to use it for treatment in the future. The preliminary results are indeed very encouraging (read our article on page14).

An obvious partnership

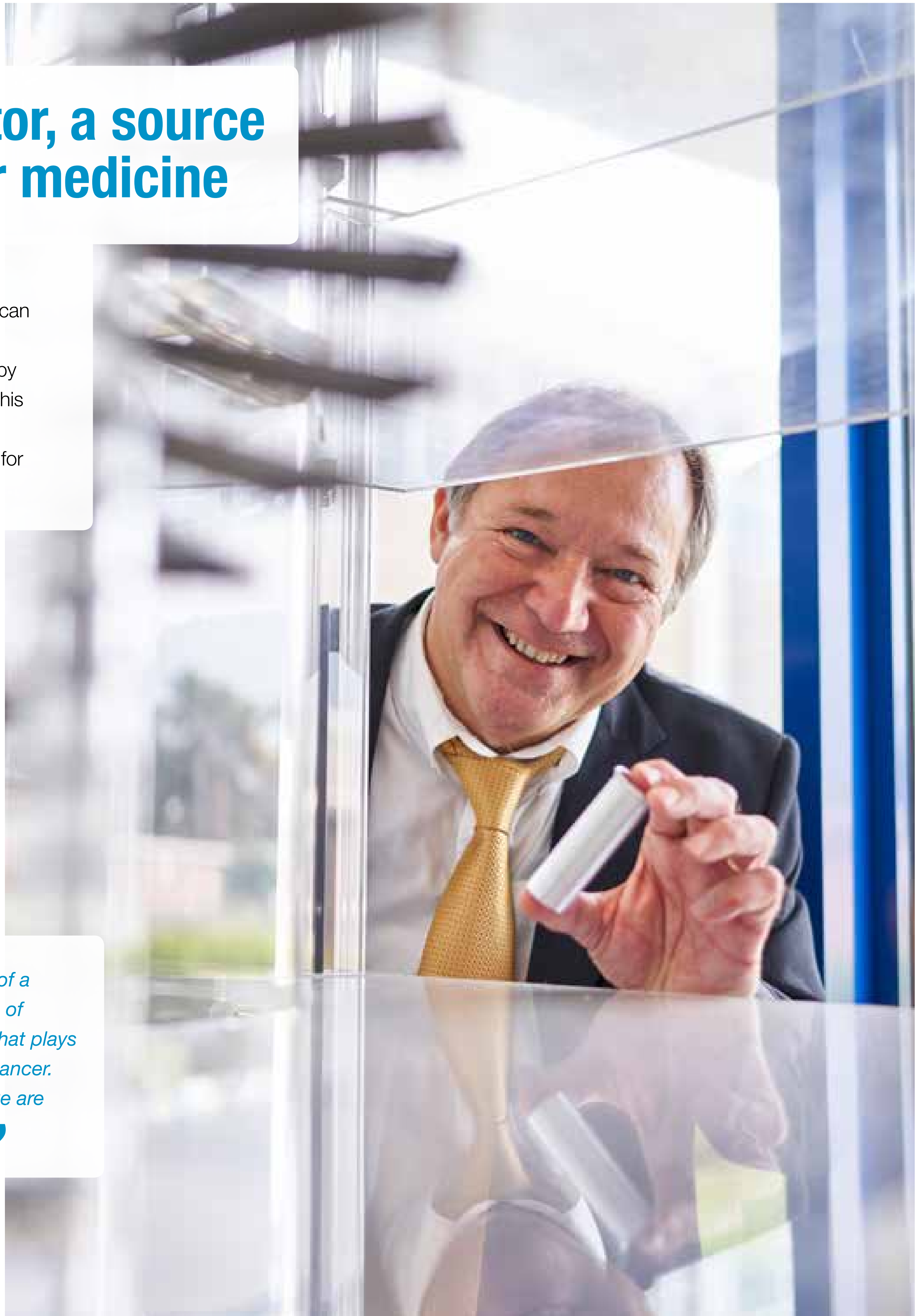
It is hardly surprising that SCK•CEN chose to join forces with this start-up, which offers huge development potential. *"Nuclear medicine is one of our top priorities at SCK•CEN. The tools offered and developed by ANMI also make use of radioelements, a key production stage of which is provided by the unique infrastructure of our research centre. It is therefore very much in our interest to see those solutions launched on the market. This will ensure a guaranteed outlet for the medical radioisotopes that we produce,"* affirmed Boland. At the end of 2017, SCK•CEN secured this partnership with a convertible loan intended for the development of ANMI. *"We are also in the process of finalising the investment to increase the capital of this start-up, which will also be used to finance a doctoral thesis at SCK•CEN relating to the innovation and the development of radiopharmaceutical compounds".*

Promising developments

While this partnership is a wonderful acknowledgement of the expertise that SCK•CEN has been cultivating since its creation, it is also proving to be a springboard to other, equally promising opportunities. *"This partnership will enable us to strengthen our expertise in the area of research into the mechanisms of action of radiopharmaceuticals, for which we are already very well positioned. In the future, we will also be in a position to be able to conduct pre-clinical studies on the basis of radioactive molecules using the accredited infrastructures of SCK•CEN",* enthused Boland.

The BR2 research reactor, a source of innovation in nuclear medicine

Let's be biased for a change. Belgium has true expertise that it can be proud of in the research and production of radioisotopes for use in nuclear medicine. This has just been proven once again by SCK•CEN's BR2 research reactor, a world renowned player in this field, with the launch of the first ever large-scale production of a lutetium isotope, which is an extremely promising development for the treatment of prostate cancer.



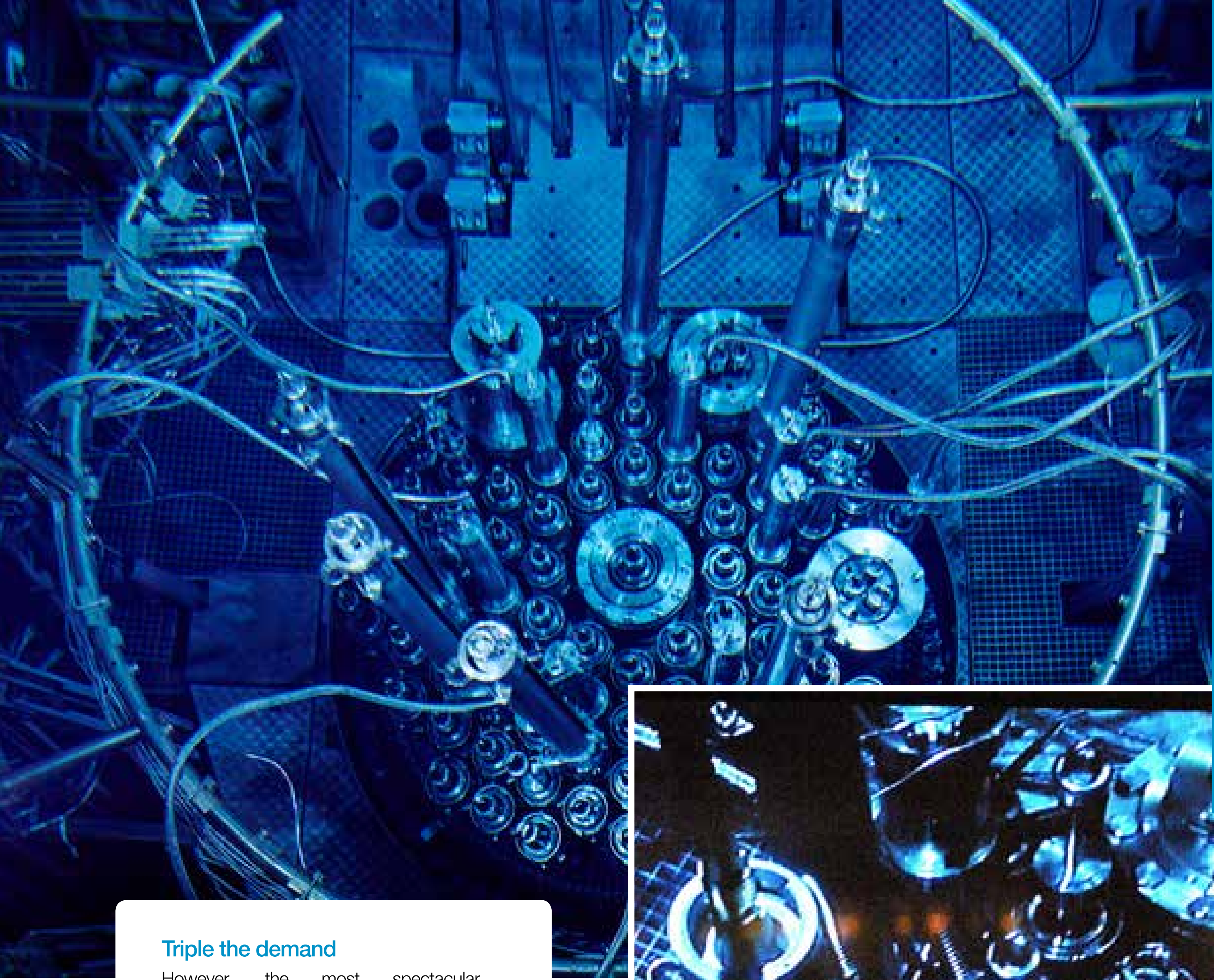
The BR2 research reactor has been a central pillar of nuclear medicine, both in Belgium and abroad, for a number of years now. It produces numerous radioisotopes for the purposes of medical imaging and cancer treatment. The BR2 possesses the greatest capacity in the world for the irradiation of targets in order to produce Mo-99, an isotope of molybdenum, for example. *"This is the main isotope that we produce,"* confirmed Bernard Ponsard, Radioisotopes Project Manager at SCK•CEN. When operational, up to 65% of the global demand for Mo-99 is produced at Mol, with that figure averaging out to around 25% across the year. Once produced, that very Mo-99 can be used to obtain an isotope of technetium, Tc-99m, a product of its decaying process, which is used in 80% of radiodiagnostic procedures worldwide. *"That equates to around 30 million examinations each year!"* pointed out Ponsard.

"Having anticipated the recent closure of a Canadian reactor, we are now capable of producing yttrium-90, a radioisotope that plays a crucial role in the treatment of liver cancer. This was a significant challenge that we are extremely proud to have overcome!"

But the team behind BR2 is certainly not resting on its laurels! For example, the irradiation devices in the reactor were adapted in 2017 to allow a new type of target to be irradiated. As a result of that modification, the reactor will, from now on, be able to produce Mo-99 from low-enriched uranium (U-235 concentration below 20%) rather than highly enriched uranium (U-235 concentration greater than 20%) in accordance with the Nuclear Non-Proliferation Treaty. An essential step that we were able to successfully overcome.

Yttrium-90 to prolong the lives of patients

Additional efforts were also made in 2017 to develop the production of other radioisotopes, particularly those used in the treatment of liver cancer. The BR2 reactor will therefore be approved for the production of yttrium-90 microspheres (Y-90). *"This isotope has already been in use for some time, but for us, this is a new area of production following on from the recent closure of a Canadian reactor, which we were able to anticipate. This was a real challenge for us and we are incredibly proud that we were able to rise to it,"* enthused Ponsard. This innovative approach, which is still under development, makes use of those Y-90 microspheres to reduce the size of liver tumours, thereby enabling them to be accessed via surgery. It also facilitates liver transplants and significantly extends survival times among patients, while also improving their quality of life.



LU-177, A RAY OF HOPE FOR PROSTATE CANCER

Prostate cancer is extremely deadly, causing around 90,000 deaths per year in Europe. One of the most promising approaches to treating it involves a combination of a beta emitter (Lu-177) and a ligand, to which it is grafted, which, in this case, is an antibody or a small molecule that attaches itself to the Prostate Specific Membrane Antigen (PSMA). This antigen, which is present on the surface of the cancer cells, seems to be more abundant the more aggressive the cancer is. It is therefore an ideal target for performing medical imaging as a first step with the help of the Ga-68-PSMA ligand. That first procedure will enable the extent of the prostate tumour to be established, together with the dose of the Lu-177-PSMA ligand that is to be administered to the patient during the second procedure in order to treat the cancerous cells.

Triple the demand

However, the most spectacular development of 2017 within the BR2 reactor, in terms of the production of radioisotopes at least, was linked to the production of a lutetium isotope, Lu-177. This radioelement, which, incidentally, takes its name from Lutetia, the ancient name of the city of Paris, is currently undergoing approval by the EU that will allow it to be marketed for the treatment of prostate cancer, the second most common cancer among men. The unique feature of this new approach, which combines diagnosis and treatment, is that it makes use of a pair of radioisotopes, Lu-177 and gallium-68 (Ga-68), which enables improved diagnosis, more precise information regarding the location and size of tumours and more effective treatment.

In any event, the results achieved during clinical trials have been encouraging. And the demand for irradiation to produce *"carrier-free"* Lu-177 (by means of the irradiation of Yb-176) and *"carrier-added"* Lu-177 (by means of the irradiation of Lu-176) has literally exploded. And this is just the beginning. *"Demand is expected to triple in the coming years,"* explained Ponsard happily. Thankfully, the BR2 reactor is already capable of handling that boom. *"We saw this demand coming and we were able to anticipate this demand to a sufficient degree to enable us to start developing additional tools that will allow us to increase our irradiation capacity. We are now fully capable of responding to current, and even future, demand".* In fact, other irradiation tools are currently being designed in order to considerably increase the current irradiation capacity. BR2 clearly is not done surprising us yet.

Cancer

Always innovating

Our BR2 reactor plays a daily crucial role in fighting against cancer on a global scale. Its medical radioisotope production allows for the diagnosis of some 250,000 patients a week but also for providing less invasive treatments. Our researchers are focusing on advancing nuclear medicine and fighting cancer, a disease which can affect all of us at some point in our lives.

Sven Van den Berghe
Nuclear Materials Science
Institute Director

ICERR: exceptional recognition for SCK•CEN

In September 2017, SCK•CEN was awarded the ICERR (International Centre based on Research Reactors) certificate by the International Atomic Energy Agency. The Belgian research centre is only the third institute in the world to receive this prestigious accolade for its scientific excellence and its unique infrastructures which makes training other IAEA Member States possible.

Launched in 2014, the ICERR certificate is awarded by the International Atomic Energy Agency (IAEA) to institutions possessing research reactors and cutting-edge technological equipment. The aim of this project is to help the IAEA Member States, particularly those that do not possess research reactors, to quickly access efficient infrastructures, to perform research and development activities, to boost their nuclear capacities and to improve their culture of nuclear safety.

Willem Van de Voorde - Belgian Ambassador in Austria
Yukiya Amano - Director-General IAEA
Eric van Walle - Director-General SCK•CEN

A world-class centre

In September 2017, SCK•CEN had the privilege of joining the extremely exclusive club for research centres that have been awarded the ICERR certificate, alongside France and Russia. This award rewards the high level of expertise and knowledge developed by the Belgian centre and the unique nature of its infrastructures starting, for example, with its BR2 research reactor, one of the most powerful and flexible on the planet.

"This award is an honour for Belgium," stated Eric van Walle, Director-General of SCK•CEN. *"It grants us the status of model research centre for the coming years and enables us to share our expertise with other countries and to strengthen our international partnerships. We are proud that our one-of-a-kind infrastructure is able to help the IAEA to achieve its objectives".*

Nuclear Academy

SCK•CEN certainly did not wait to be rewarded in this manner for sharing the fruits of its many years of expertise. In 2017, some 1600 students and professionals followed an education or training programme within its Academy. In addition, almost one hundred bachelor's and master's students completed an internship or a thesis within SCK•CEN's laboratories. And, last but not least, 87 doctoral students chose to launch their research projects at the nuclear centre in Mol.

"The ICERR certificate was also awarded in recognition of our excellence in education and training," added Michèle Coeck, Head of the SCK•CEN Academy. *"Thanks to our broad catalogue of bespoke training courses, we are able to pass on the expertise acquired via our R&D activities to current and future generations. Our nuclear installations and our research reactors in particular are an indispensable asset in this regard".* In the world of nuclear research, Belgium is now glowing with renewed vigour.

> *"We are proud that our one-of-a-kind infrastructure is able to help the IAEA to achieve its objectives."*

02

MYRRHA gains impetus

Full MYRRHA file in the hands of the Belgian government

2017 was a year of intense preparation for the MYRRHA team. Eleven reports, studies and detailed documents, also known as *High Level Deliverables,* needed to be submitted to the Belgian government in order to move the project forward. Mission accomplished: the finalised documents have been in the hands of government experts since December 2017. The teams behind MYRRHA are extremely pleased with the way things are going.

Generally aimed at stakeholders that are external to a company, the *deliverables* are a cornerstone for the management of any project and they also provide a guarantee of its tangible nature, its visibility and, last but not least, its success. It was with that in mind that the MYRRHA team went about responding, on schedule, to the request from the Belgian government, providing it with a total of eleven *High Level Deliverables* detailing the progress of the project.

Deadlines met

"The first deliverable consisted of describing the accelerator assembly from a technical viewpoint, from 0 to 600 MeV (megaelectronvolts), together with all of the components of that infrastructure. Our designs for that accelerator are sufficiently far advanced to enable us to describe it in detail," explained Hamid Aït Abderrahim, Director of the MYRRHA project. *"A preliminary version of that deliverable was submitted to the government in September 2017. We then provided it with an update at the end of last year".*

Another document submitted to the MYRRHA Ad Hoc Group (MAHG), the project follow-up committee established by the government in 2010, is that concerning the infrastructures associated with the first phase of the project. *"That report was also completed during September 2017 and was submitted within the deadline set,"* enthused Abderrahim. The Belgian authorities also requested a commercial and financial plan covering the whole of the project (see article on page 32); this was completed in June, 2017. *"We then submitted it to the National Bank of Belgium to be checked and analysed".*

"The effort involved in this was rather intense. Everybody needed to be involved and there were numerous meetings with the follow-up committee of the MAHG. However, the fact that we succeeded in meeting this objective on schedule is a source of great satisfaction for the entire team"

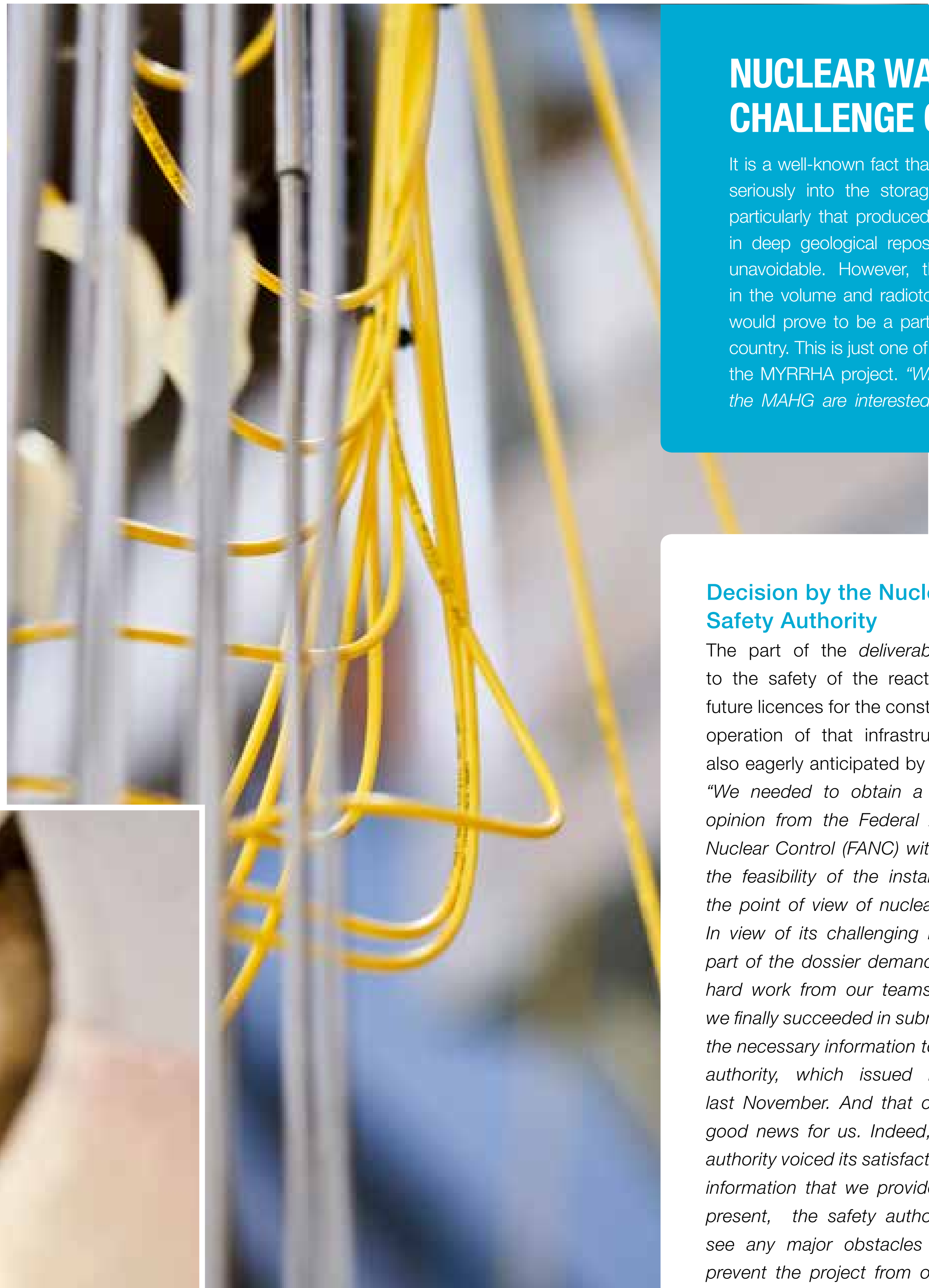
700 JOBS/YEARS

6.900.000.000 OF ADDED VALUE

150 EMPLOYEES

30 NATIONALITIES

38 PHD STUDENTS



NUCLEAR WASTE: THE CONFIRMED CHALLENGE OF MYRRHA

It is a well-known fact that Belgium is looking very seriously into the storage of radioactive waste, particularly that produced in our nuclear facilities, in deep geological repositories. Such storage is unavoidable. However, the significant reduction in the volume and radiotoxicity of these elements would prove to be a particular advantage for our country. This is just one of the flagship ambitions of the MYRRHA project. *"What the government and the MAHG are interested in is seeing the extent to which we will be able to apply this technology to nuclear waste in order to reduce the amount of geological storage required by Belgium,"* explained Abderrahim. *"Our teams have performed studies in this regard and have been able to demonstrate that the use of MYRRHA would enable a reduction to be made in the volume of waste needing to be stored underground. The volume of such geological storage would be reduced by a factor of 5, which is far from negligible!"*

Decision by the Nuclear Safety Authority

The part of the *deliverables* related to the safety of the reactor and the future licences for the construction and operation of that infrastructure were also eagerly anticipated by the MAHG. *"We needed to obtain a preliminary opinion from the Federal Agency for Nuclear Control (FANC) with regard to the feasibility of the installation from the point of view of nuclear approval. In view of its challenging nature, this part of the dossier demanded a lot of hard work from our teams. However, we finally succeeded in submitting all of the necessary information to the safety authority, which issued its opinion last November. And that opinion was good news for us. Indeed, the safety authority voiced its satisfaction with the information that we provided to it. At present, the safety authority cannot see any major obstacles that could prevent the project from obtaining its licence,"* explained the Director of the MYRRHA project.

Objective, phase 1

"The final versions of all of those high-level deliverables were submitted to the government on 15 December 2017," continued Abderrahim. *"The effort involved in this was rather intense. Everybody needed to be involved and there were numerous meetings with the follow-up committee of the MAHG. However, the fact that we succeeded in meeting this objective on schedule is a source of great satisfaction for the entire team. We are delighted, because all our hard work will enable our government to come to a decision regarding the future of the MYRRHA project with all of the necessary information at their fingertips,"* clarified the man responsible for the destiny of this unprecedented project.

MYRRHA adopts a robust commercial and financial plan

The MYRRHA project now has a commercial and financial plan that will take it through to 2067. It is the most comprehensive and detailed plan to date. As well as having been submitted to the project follow-up committee established by the Belgian government, the plan has also been successfully presented to numerous potential investors. This bodes well for the continuation of the MYRRHA project.

The raising of capital for any self-respecting major project is always accompanied by a financial and commercial plan aimed at potential investors. The MYRRHA research infrastructure is no exception to that rule. With regard to the next steps of the public funding of MYRRHA, a budgetary framework has therefore been drawn up by the team at the centre, at the request of the Belgian government. That plan was submitted to the MYRRHA Ad Hoc Group (MAHG), the project follow-up committee established by the government in 2010, together with ten other high-level reports, known as *High-Level Deliverables* (see article on page 28).

Complete estimate of costs

"This isn't the first business plan that has been drawn up for MYRRHA, but it is by far the most complete," explained Stijn Proost, Stakeholder Manager at MYRRHA. *"All of the details of the project have been gathered together, not just for the construction period, as was the case with previous versions, but for the entire life span of the infrastructures, which contributes to the robust nature of the end result".*

Not necessarily an easy task given the innovative nature of the MYRRHA project. *"The thing that sets MYRRHA apart is its long-term vision: this is an infrastructure that is expected to remain operational until 2067. It's really not easy to project so far into the future,"* stressed Proost. *"Another significant challenge: estimating costs, knowing that MYRRHA is the first project of its kind. The calculation of costs, which takes place in close collaboration with the scientific and technical team, demanded a significant amount of work. Finally, we also needed to make estimates regarding the sources of funding, not only taking account of construction costs, but also the annual operating costs,"* continued Proost.

A robust and detailed plan

In addition to being submitted to the Belgian government, another equally essential step has already been embarked upon in connection with MYRRHA's commercial and financial plan. Principal objective: to pique the interest of potential investors. *"We cannot ask for funding amounting to 1.6 billion euros without providing guarantees and without providing a detailed explanation of what that money will be used for, together with a description of the various stages of the project,"* pointed out Proost, logically. Some countries, such as France, Germany and Japan, are interested in any event. *"These have also been joined by a range of private or institutional investors, such as the EIB (European Investment Bank), which are even more likely to demand a robust and detailed financial plan."*

Potential investors

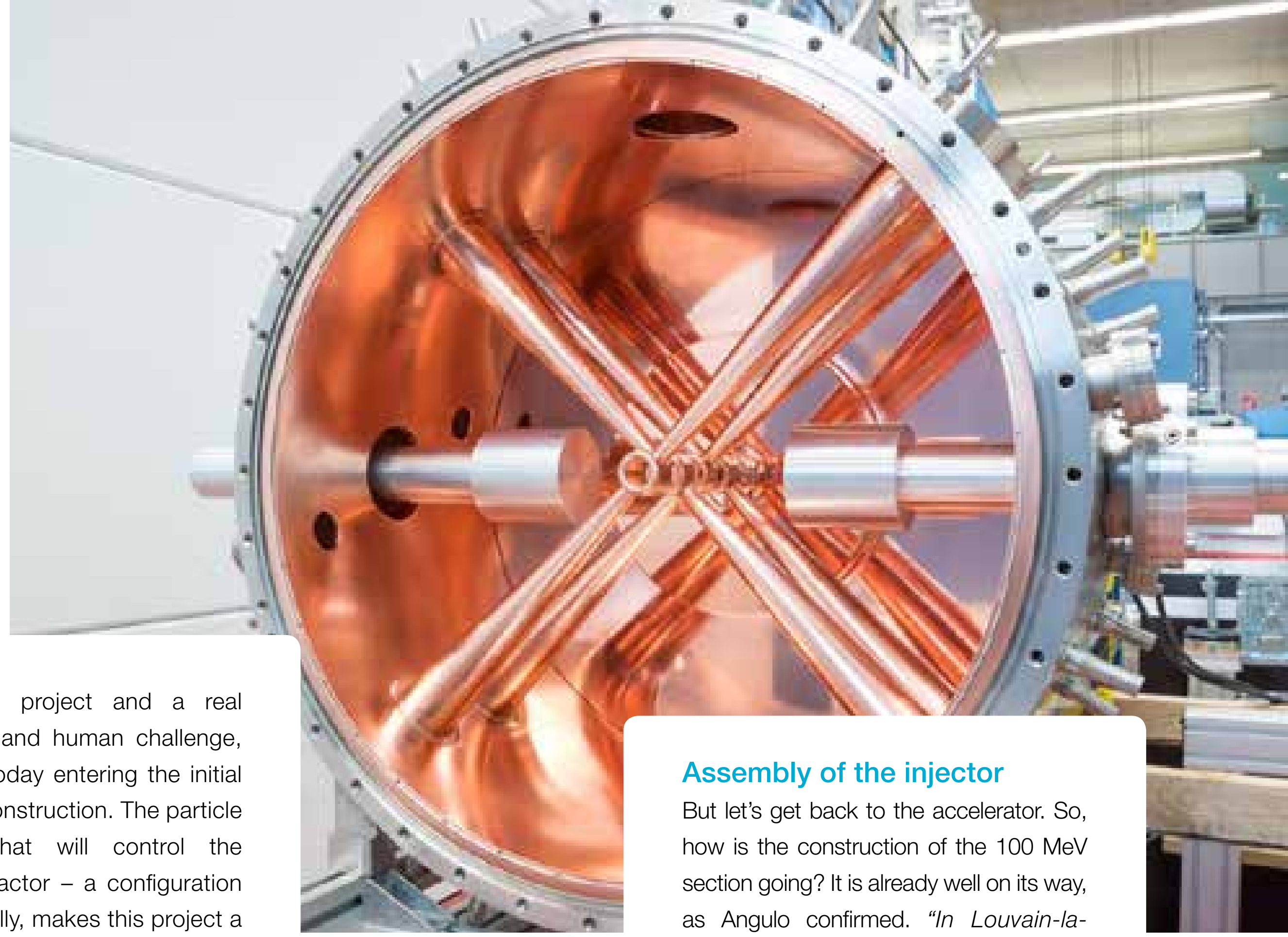
Efforts to find partners have already begun. Between 2017 and 2018, the commercial and financial plan was used to present and defend MYRRHA during more than fifty meetings with national and international decision-makers. And with some success. *"Most notably, we have succeeded in having it appraised by certain private companies that are active in the industry as well as some purely financial stakeholders, such as the Flemish organisation, PMV (ParticipatieMaatschappij Vlaanderen),"* added Proost. *"The feedback regarding the quality of the plan has been very positive. The financial contacts and captains of industry with whom we have been able to speak recognise the social utility of the project".*

Belgian expertise

Unique project of global importance

If MYRRHA saw the light of day on Belgian soil, it has since then constantly been looking for collaborations around the globe. The challenges that MYRRHA rose to, whether in the management of high-level nuclear waste or innovation in nuclear medicine, make it a real hub for international R&D. The establishment of an international consortium of investors will further boost the essential role played by Belgium on a global scale.

Peter Baeten
Deputy Director-General



MYRRHA phase 1: objective 100 MeV

The construction of the MYRRHA research infrastructure is entering a crucial phase. During this initial phase of the project, the energy of the particle accelerator that will control the future MYRRHA nuclear reactor will be increased to 100 MeV. At the same time, experts will develop research stations that will be linked to that accelerator in order to produce new-generation medical radioisotopes and to perform fundamental and applied research into materials for nuclear fusion, among other things.

An ambitious project and a real technological and human challenge, MYRRHA is today entering the initial phase of its construction. The particle accelerator that will control the sub-critical reactor – a configuration that, incidentally, makes this project a world first – will actually be built on a step-by-step basis in order to reduce the technological risks and to stagger the investments. A sensible strategy.

MINERVA, an integral infrastructure

"Phase 1 involves the construction of the section of the accelerator that will produce up to 100 MeV (megaelectron-volts) of energy. The initial aim is to test the reliability of this part of the system," explained Carmen Angulo, head of the MINERVA project. *"This initial phase also includes all of the research and development relating to the reactor, as well as the part of the accelerator that will achieve up to 600 MeV".*

However, the construction of that first part of the accelerator will not just serve to evaluate the future reliability of the MYRRHA accelerator. The proton beam produced by this part of the accelerator will be put to the very specific use of performing research into materials for nuclear fusion and the production of innovative radioisotopes. *"During phase 1, we will, in fact, be diverting a part of the beam produced by the accelerator towards targets that will enable new isotopes to be produced for use in experiments in the fields of physics and medicine. Known as MINERVA, this infrastructure, which is made up of the accelerator and the targets, represents an important milestone for the MYRRHA project,"* explained Angulo.

Assembly of the injector

But let's get back to the accelerator. So, how is the construction of the 100 MeV section going? It is already well on its way, as Angulo confirmed. *"In Louvain-la-Neuve, we are busy installing the first part of the accelerator, which is known as the injector. This is a very important step. That injector is responsible for all of the aspects associated with the feasibility and reliability of the project,"* explained our project leader.

The prototypes for the sixteen accelerating cavities of the injector (see boxed text) were designed in collaboration with the German institution IAP *(Institut für Angewandte Physik)*, at the University of Frankfurt, which is renowned for its expertise in this field, as well as with its spin-off, Bevatech GmbH. The first two cavities manufactured for SCK•CEN are currently undergoing testing at the IAP.

> *"In Louvain-la-Neuve, we are busy constructing the first part of the accelerator, which is known as the injector. This is a very important step. That injector is responsible for all of the aspects associated with the feasibility and reliability of the MYRRHA project."*

A LINEAR ACCELERATOR

The MYRHHA project essentially consists of a sub-critical reactor, fuelled by an external source of neutrons. That source is created by bombarding a target of lead-bismuth liquid at the centre of the reactor core with the intense beam of protons generated by a high-powered particle accelerator. To achieve maximum reliability, the MYRRHA experts have opted for a linear accelerator, known as a linac. The accelerator has a length of almost 300 metres, which enables the proton beam to achieve 600 MeV of energy.

The concentration and acceleration of the beam are ensured by a succession of magnets and cavities, some of which are cooled using liquid helium in order to trigger superconductivity within the material. Thanks to that superconductivity, energy losses are drastically reduced within the accelerator. At the end of the accelerator tunnel, the beam is diverted, with the help of magnets, to the top of the reactor room, where it is diverted once again so that it drops vertically into the centre of the reactor core from above.

A highly technical specification

In the meantime, the teams at SCK•CEN are also busying themselves with designing and preparing for the construction of the buildings that will house the various elements of the first phase of MYRRHA. Everything is well on its way in this regard too. *"The preliminary designs for the buildings intended to house the 100 MeV section of the accelerator and the auxiliary systems are ready. We have launched an invitation to tender to find an industrial partner that will be tasked with preparing the construction phase. Once we have made our choice, we will submit our specifications to the company in question. These specifications are extremely technical and we must be certain that our requirements will be met. On the other hand, we are also in the process of designing the housing for the targets and will have completed this by the end of 2018,"* emphasised Angulo. There is no doubt that phase 1 of MYRRHA is heading in the right direction!

03

Diving into outer space

From the white continent to the red planet

We have taken a further step towards Mars by placing test tubes and microscopes on board the Princess Elisabeth polar research station; Sarah Baatout, a researcher at SCK•CEN, is one of those who stepped up to this audacious challenge, together with her entire research team. She spent a month immersed in extreme conditions of confinement in order to understand better the way that our immune system behaves in space! Such data are invaluable when it comes to advancing both space and medical research.

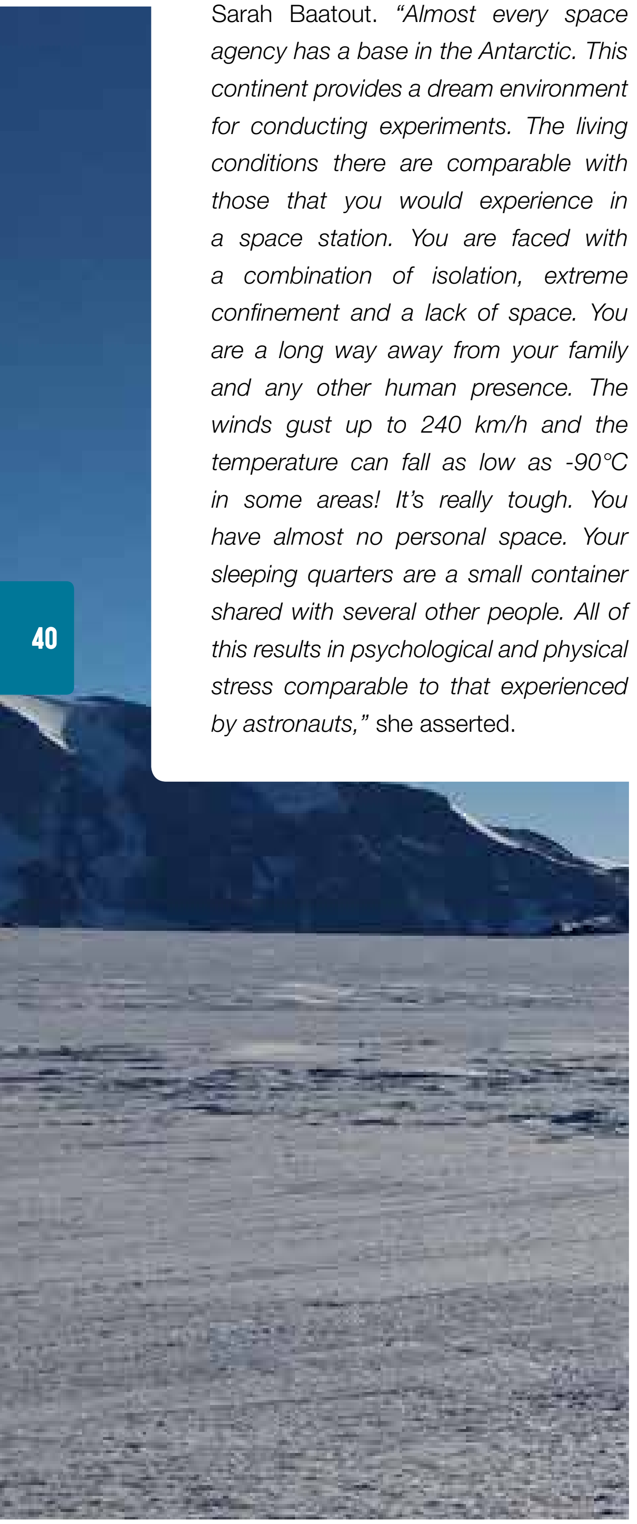
Radiobiologist, mother of two, talented ice skater and university guest professor: Sarah Baatout is simply full of ideas and projects. At the end of 2017, the Belgian researcher saw one of her dreams come true: visiting the Princess Elisabeth polar research station to perform research into space flight. Selected from around twenty Belgian and international scientists, she flew out to Antarctica on 16 December last year following a long period of scientific, physical and psychological preparation.

Head of the radiobiology unit at SCK•CEN, Sarah also has a bit of a tendency to reach for the stars! For a number of years now, she has been working together with her colleagues in the laboratory to examine the impact of cosmic rays and extreme conditions (confinement, stress, isolation) on the human immune system. The research provided a better understanding of the way in which an astronaut's body functions in space and the development of applications that will one day enable humans to fly to Mars.

SPICES AND SALT GALORE!

One of the most surprising things about the extreme cold that prevails in Antarctica is that it almost completely neutralises your senses of taste and smell. *"You can barely smell anything. It's incredible,"* said Sarah. *"You barely even notice the smell of kerosene around the vehicles. The same is true of your sense of taste. At the station, you have to use five or six times the amount of spices that you would normally use. And more salt too. It would be completely inedible here!"*

"I hope that I was able to pass on my passion for science to the children and to spark an interest among them."



The polar research station: a space simulator

However, what does her recent and very cold polar stay have to do with a future departure to our solar system's fourth planet? "*It might seem a bit of a paradox, but that's really not the case,"* exclaimed Sarah Baatout. *"Almost every space agency has a base in the Antarctic. This continent provides a dream environment for conducting experiments. The living conditions there are comparable with those that you would experience in a space station. You are faced with a combination of isolation, extreme confinement and a lack of space. You are a long way away from your family and any other human presence. The winds gust up to 240 km/h and the temperature can fall as low as -90°C in some areas! It's really tough. You have almost no personal space. Your sleeping quarters are a small container shared with several other people. All of this results in psychological and physical stress comparable to that experienced by astronauts,"* she asserted.

Full medical check-up

That is why Sarah sought out those freezing conditions for an entire month. *"Thankfully, it was summer down there. There were some days when the weather was extremely good, warm even, and others where the weather was so atrocious that we had to remain indoors. We were not allowed to leave at all,"* reminisced our researcher-cum-adventurer. But the rigours of Antarctic life did not prevent her conducting her vital experiments; quite the opposite, in fact. *"One of the aims of our study was to measure the reaction of the immune system to polar living conditions. In the Antarctic, organisms are generally immunosuppressed during the first week. This is just one of the points that a polar stay and a trip to space have in common. With the help of regular blood tests, we have been able to verify the amount of time it takes the body to recover its immune function. We also performed cardiac monitoring of members of the station, together with oxidative stress testing by means of saliva and urine analyses, which are excellent stress markers".*

Space medicines

Let there be no mistake. All this research aimed at making manned space flight possible also contributes to advancements in the field of medicine. An example of this is proton therapy, which came about, in part, as a result of space research. During her polar mission, the SCK•CEN researcher also set herself an additional objective: to test the medical kit with which the astronaut of tomorrow will be equipped. And who knows, perhaps also the terrestrial hospitals of the future. *"We had with us around twenty different drugs that astronauts take with them when they go into orbit,"* added Sarah. *"We left them exposed on the roof of the polar research station in order to study their behaviour when faced with massive doses of UV radiation. Antarctica experiences almost 24-hour daylight at this time of year. The idea was to see the speed with which the drugs degrade when subjected to the effects of cosmic rays and extreme cold with a view to subsequently calculating the doses to be administered to astronauts. This is all the more important given that the effectiveness of certain drugs differs when they are in space. Some become more effective, others less so".*

"I rubbed shoulders with some extraordinary people, I experienced moments of sharing and closeness that are all too rare during our everyday lives. It was completely unique."

An unforgettable experience

"This month-long experiment is just the tip of the iceberg. The project demanded an immense amount of teamwork. My colleagues had to demonstrate a great deal of creativity and flexibility in order to guarantee the scientific success of this experiment," emphasised Sarah, who takes a great deal of pride in her trip. *"We had to change our protocols to adapt them to the safety constraints and to reduce our equipment to the bare minimum, since there were weight restrictions imposed on what we could bring. I had to learn to perform repairs myself for the same reasons. It required a great deal of preparation, but the satisfaction was enormous".* And what an adventure it was! Her stay on the white continent was a truly unforgettable experience for Sarah. *"It's still too early to draw any conclusions on the basis of our analyses, but I had the most fantastic personal experience down there. I rubbed shoulders with some extraordinary people, I experienced moments of sharing and closeness that are all too rare during our everyday lives. It was completely unique".*

EDUCATIONAL PROJECT

For this insatiable researcher and her ever-increasing number of educational projects, sharing her adventure with youngsters was a no-brainer. *"I managed to connect to the internet for up to 3 hours each day,"* enthused Sarah. *"I used that time to explain my mission to classes of primary and secondary school children via videoconferences. I spoke to between four and six schools each day. I hope that I was able to pass on my passion for science and to spark an interest among them".*

“Belgian” cyanobacteria conquering space

On 15 December 2017, the SpaceX CRS-13 rocket lifted off from the Kennedy Space Centre in Florida, headed for the International Space Station. On board was the world’s first photobioreactor, developed by microbiologists from SCK•CEN in collaboration with the European Space Agency, the MELiSSA scientific consortium and the company QinetiQ Space. This unique experiment is one small step towards a system that will enable the autonomous production of oxygen and food for future long-duration manned flights and one giant leap towards the coveted destination of the planet Mars...

Belgium, a gateway to the stars? Yes, or at least to Earth’s immediate neighbourhood for the time being. For a number of years now, SCK•CEN has been making a name for itself in the field of space research and has been regularly sending experiments into orbit around our blue planet. However, the most recent of these undoubtedly marks a turning point for making a great dream come true: travelling to Mars and, who knows, possibly even further someday.

The challenges posed by space

In the meantime, there is still a great deal of progress to be made before we are even able to set foot on the red planet. *“The greatest challenge for getting there is procuring enough food and water for the teams embarking on such a mission. Indeed, it would no longer be possible to fly out additional supplies in the way that we do today,”* pointed out Natalie Leys, who is responsible for the Space Life Science Program at SCK•CEN. However, this is not the only challenge awaiting the future astronauts heading for the cosmos; they will also face near-zero-gravity conditions and even harmful cosmic radiation, to name just two. *“As long as we remain under the shield provided by Earth’s magnetosphere, our bodies are protected from the effects of that radiation. However, this is no longer the case when we venture beyond that shield,”* remarked the microbiologist. The daily dose of ionising radiation is therefore significantly higher in space than it is on Earth. On the International Space Station (ISS), which still benefits from some protection from the magnetosphere, the levels of radiation are typically around 200 times higher.

Space compost

Will the road to Mars and the stars beyond be permanently closed? We should not underestimate the ingenuity of the scientists working on manned space travel programmes. *“For example, space agencies are envisaging solutions that will allow crews to produce their own water, food and oxygen by reclaiming their waste. That is precisely what the European Space Agency is aiming to achieve with its MELiSSA project, which was co-founded by SCK•CEN,”* continued Leys. But how will they achieve this? You cannot take a vegetable plot and its compost heap into space: it would be too heavy and cumbersome! *“The idea is to instead recreate a part of Earth’s aquatic ecosystem using* »

“We had to design a photobioreactor capable of functioning in the challenging conditions of space. This posed a major scientific and technological challenge, but we succeeded and are extremely proud of the result!”

sophisticated (photo)bioreactors to fuel the production greenhouses. This involves the creation of a kind of space compost. We plan to make use of micro-organisms to enable us to recycle organic and inorganic waste to produce nutrients for the plants. As some of these are edible, they could also be consumed by the astronauts," explained Leys.

First photobioreactor in space

Since the flight of Belgian astronaut Frank De Winne, several micro-organism cultures have been sent into space by our research centre. *"Up until now, these have been less complex experiments,"* clarified Leys. However, in December 2017, following ten years of intensive research, SCK•CEN has gone one step further: rather than sending just a *"simple"* Petri dish to the ISS, it has sent a truly sophisticated photobioreactor, containing spirulina, one of the most interesting of the cyanobacteria (see opposite). *"This was a European, and almost certainly a world first!"* enthused Leys. *"The culture in question was actively fed and monitored remotely. The experiment lasted five weeks, during which time the astronauts were even able to harvest some samples. The aim was to test the behaviour of the spirulina and the production of oxygen in the presence of microgravity and space radiation. We have therefore succeeded in designing a photobioreactor capable of functioning in those challenging conditions. This posed a major scientific and technological challenge, but we succeeded and are extremely proud of the result!"*

An unexpected harvest

In any event, the preliminary results are extremely promising, and some have even come as quite a surprise to the scientists working on the Space Life Science Program: *"Oxygen production are almost the same as they would have been on Earth. The final output even turned out to be greater than expected, but we don't yet know why,"* enthused Leys. *"There are, of course, some things that need to be improved upon, but we now know that this type of bioreactor will work. This is a crucial first milestone!"*

©NASA

SPIRULINA, FUTURE ASTRONAUT FOOD?

Easy to produce and capable of quickly converting organic and inorganic materials into nutrients and biomass, certain micro-organisms are ideal candidates for stocking the pantries of the astronauts of the future. Among them are the Arthrospira cyanobacteria, better known as spirulina, which are proving to be model pupils. *"They have the advantage of growing by means of photosynthesis, just like plants,"* explained Leys. *"However, unlike conventional vegetables, they can be cultivated in very small areas. They also consume the CO2 in the atmosphere and recycle it into oxygen, which is extremely useful in the enclosed environment of a spacecraft. What's more, they are completely edible and are proving to be an important source of protein. And that's not all, they are also especially resistant to cosmic radiation!"*

Innovation

SCK•CEN pushes back the frontiers of innovation

We travel all over the world, trace particles of the atmosphere through models and even consider using space as our playground. We explore frontiers to push them back and make impossible seem possible. How? By innovating even more. Alone or as part of a team, but always with a never-ending enthusiasm, burning curiosity and constant concern of working for the society.

Hildegarde Vandenhove
Environment, Health and Safety
Institute Director

In pursuit of the elusive sterile neutrino

Born of a collaboration between Belgium, France and the United Kingdom, a new type of detector has been constructed at SCK•CEN in an attempt to demonstrate the existence of the sterile neutrino. This elementary particle, the existence of which is purely theoretical at present, could make up the bulk of the mysterious "dark matter", one of the main components of the universe.

Quarks, leptons, bosons... these are just some of the names making up the strange and fascinating menagerie of elementary particles, which are the most basic elements of the universe. Among these particles, neutrinos are just that little bit different. Almost undetectable, they barely interact with matter. Each second, billions of neutrinos that have been ejected by the Sun pass through our bodies without any effect.

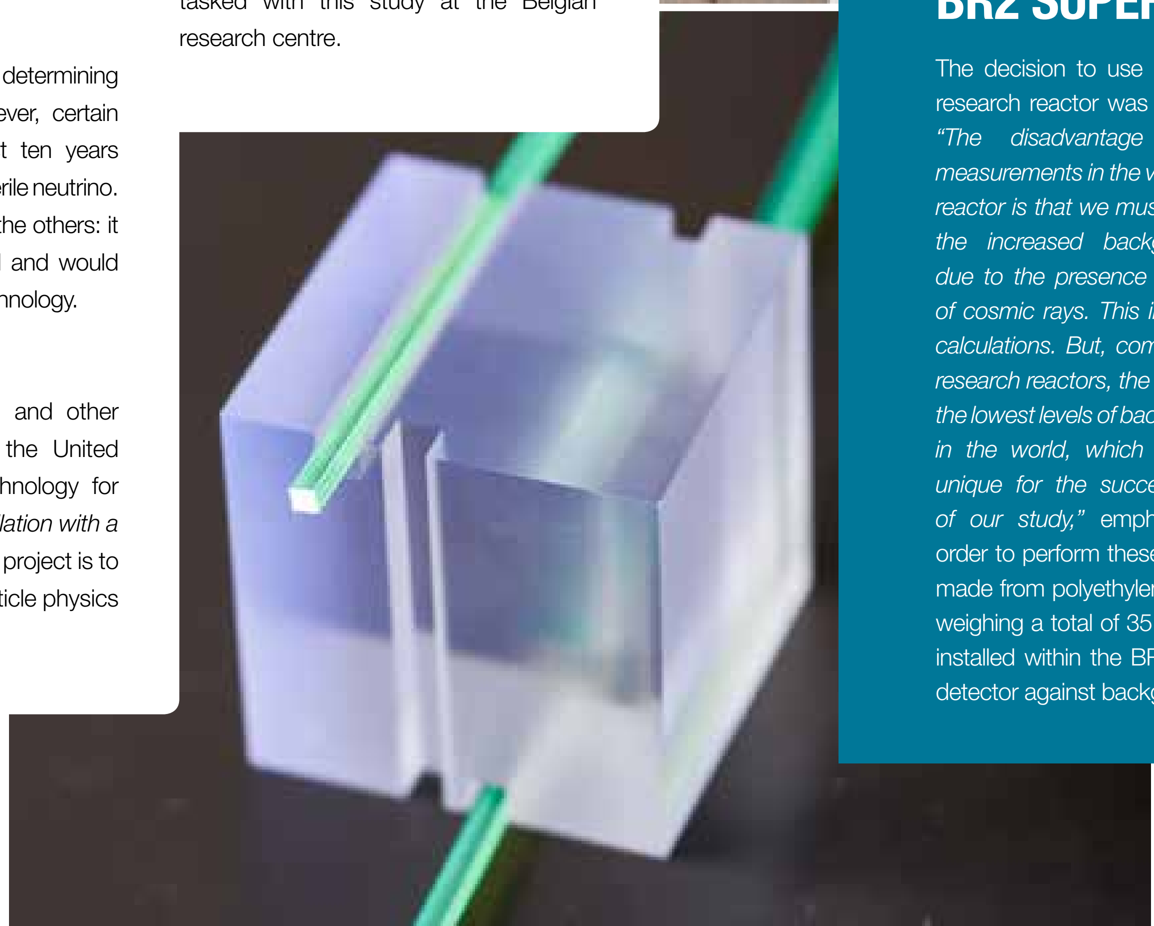
We have succeeded in proving the existence and determining the characteristics of three types of neutrino. However, certain anomalous measurements observed during the last ten years suggest the existence of a fourth type of neutrino: the sterile neutrino. And this could prove to be even more surprising than the others: it is believed that it does not interact with matter at all and would therefore be impossible to detect using our current technology.

On the hunt for neutrinos

Since 2013, a consortium made up of SCK•CEN and other research centres based in Belgium, France and the United Kingdom have been developing an innovative technology for detecting neutrinos. Known as SoLid (*Search for oscillation with a Lithium-6 detector*), the principal aim of this ambitious project is to answer one of the most fundamental questions in particle physics today: do sterile neutrinos actually exist?

As the sterile neutrino is, by definition, undetectable, scientists have no other choice than to look for it in a roundabout way, by scrutinising their indirect efforts. *"We know that neutrinos are generated en masse by nuclear reactors. We will therefore measure the flow of neutrinos emitted by SCK•CEN's BR2 research reactor with unprecedented precision to see if we are able to detect differences, anomalies, when compared with the values that we are expecting to measure, which would suggest the existence of sterile neutrinos,"* explained Lars Ghys, one of the physicists tasked with this study at the Belgian research centre.

Lars Ghys and Bernard Coupé, team members of SoLiD



An extremely SoLid detector

As other experiments of the same type have not necessarily been conclusive, scientists from the SoLid consortium have created a neutrino detector of a type never before seen, which is actually, more specifically, an antineutrino detector. The assembly weighs 1.6 ton and is made up of small, 5-cm cubes of plastic. There are no fewer than 12,800 of these in total.

The neutrinos that pass through this material trigger a reaction, a sort of very brief flash of light: *"It is that signal that we are capable of detecting and localizing with an unprecedented accuracy. The highly segmented nature of our detector, with its 12,800 cubes, makes it the only one of its kind in the world. Its spatial sensitivity is unrivalled,"* stressed Lars Ghys.

An improved understanding of the universe

This experiment, which has been under way in Mol since December 2017, has already returned several terabytes of data. These are currently being analysed and interpreted. The initial scientific results are expected in the coming months. Nevertheless, several years of research will need to take place before any final conclusions can be drawn.

But let's allow ourselves to dream a little. What would be the implications of the discovery of a new type of elementary particle? Do you envisage any practical applications? *"We don't know yet, but we could, for example, imagine using the new detector technology to fight the proliferation of nuclear weapons. As neutrinos travel unhindered across vast distances, they could be used to detect various radioactive materials produced within a specific reactor without us having to get too close to it,"* speculated Bernard Coupé, researcher at SCK•CEN and member of the SoLid team.

However, it is in the field of fundamental research that the discovery of the sterile neutrino could prove to be the most revolutionary. *"Proof of their existence would be of huge significance in the world of particle physics. Sterile neutrinos could also be an essential component of dark matter, which makes up a part of the universe. This matter is invisible, but we know that it exists!"* enthused Lars Ghys.

" The highly segmented nature of our detector, with its 12,800 cubes, makes it the only one of its kind in the world. Its spatial sensitivity is unrivalled "

BR2 SUPERSTAR

The decision to use SCK•CEN's BR2 research reactor was far from random. *"The disadvantage of performing measurements in the vicinity of a nuclear reactor is that we must take account of the increased background radiation due to the presence of the reactor or of cosmic rays. This interferes with the calculations. But, compared with other research reactors, the BR2 offers one of the lowest levels of background radiation in the world, which makes it almost unique for the successful completion of our study,"* emphasised Ghys. In order to perform these tests, a housing made from polyethylene and water and weighing a total of 35 tonnes has been installed within the BR2 to insulate the detector against background radiation.

04 At the forefront of progress

Better protection for the medical staff's eyes

SCK•CEN's expertise in the field of dosimetry is frequently highlighted at international level. Between 2015 and 2017, the Belgian research centre was entrusted with the coordination of Euraloc, the largest European study ever conducted into cataracts caused by ionising radiation in a clinical setting. Although the results of this study have only just been released, SCK•CEN is also working on developing an exclusive dosimeter intended for use by medical professionals.

Medical research on radiation is progressing relentlessly. The most recent example of this is the prevention of radiation-induced cataracts, a field in which SCK•CEN has gained a great deal of renown. It has long been known that ionising radiation can bring about changes in the lens, the most radiation-sensitive part of the eye, which causes a continuing process of opacification that can lead to the formation of a cataract.

"Until recently, it was widely accepted that there was no risk below a certain occupational exposure threshold. However, radiation-induced cataracts have undoubtedly proven to be more common than was previously thought. This has been proven by several recent epidemiological studies, as well as by research using animal models," explained Lara Struelens, head of the Research in Dosimetric Applications unit.

In 2012, the ICRP (International Commission on Radiological Protection) made a radical change to the exposure limit for the lens in its recommendations for the prevention of cataracts, reducing it to 0.5 Gy (Gray) as opposed to the previous value of 2 Gy. It also reduced the annual occupational exposure limit from 150 to 20 mSv (millisieverts).

A world first

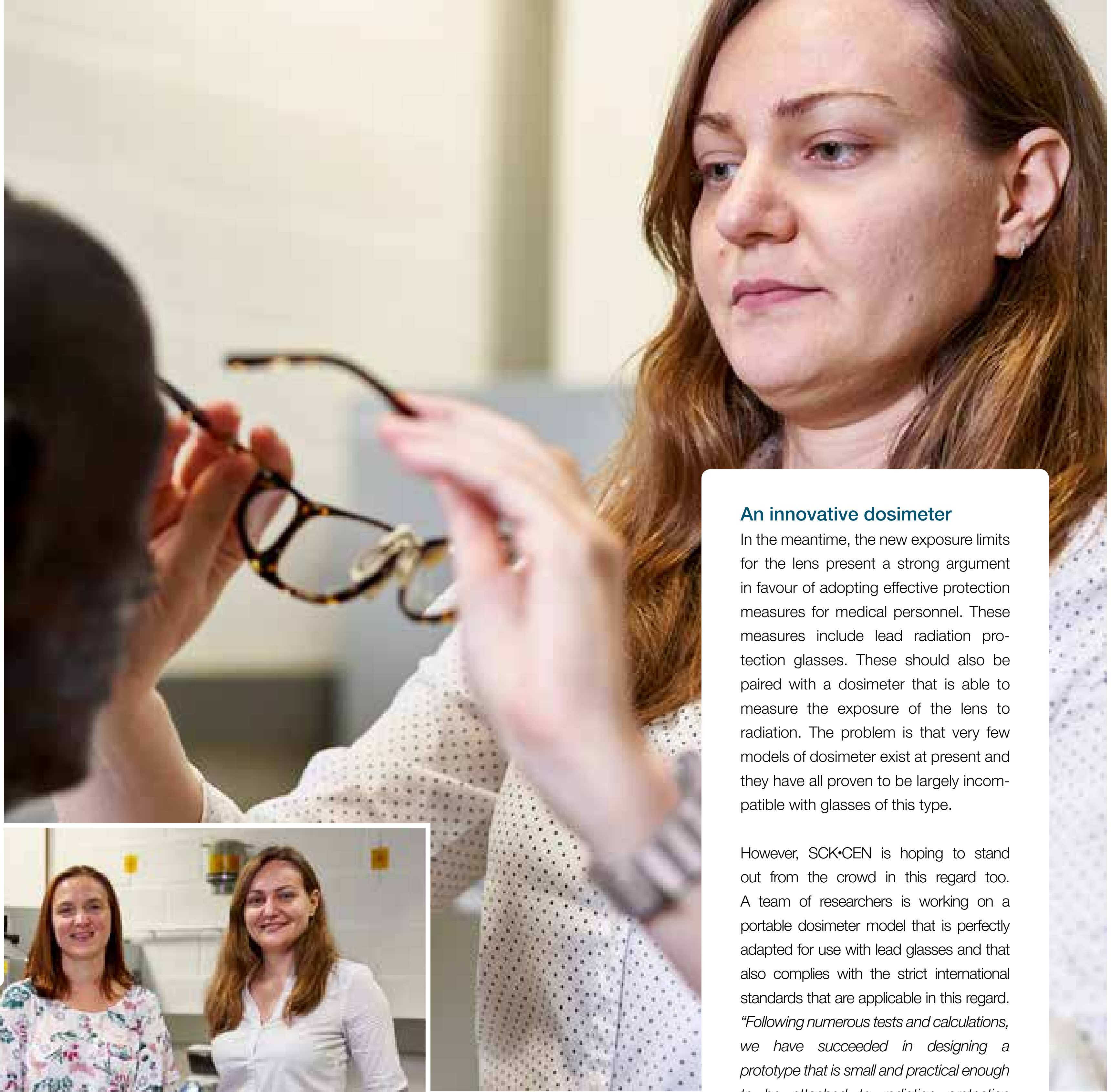
Nevertheless, the adoption of these new thresholds gives rise to a question to which there is no satisfactory response: what is the relationship between dose and effect when exposed to low doses? *"The quality of the data gathered so far has not enabled us to determine the dose at which opacification of the lens becomes a concern. That is why the Euraloc European study was launched under the coordination of SCK•CEN,"* added Struelens.

For the purposes of this epidemiological study, the largest ever carried out on this subject and on this group of people, 393 interventional cardiologists were recruited across eleven countries and were monitored in accordance with a single protocol. Under the management of SCK•CEN, dosimetry calculations were also carried out. This is also a world first; exposure of the lens to ionising radiation is not recorded by default and therefore »

"The results of our study appear to show that the higher the dose, the greater the risk and that there is no threshold under which there would be zero risk."

individual data for cardiologists were not all available. A control group was also established, consisting of 243 people who had not been exposed. But why interventional cardiologists? *"Among medical professionals, they are the ones who are the most heavily exposed to ionising radiation,"* explained Struelens.

The results of that Euraloc study are now known. *"We have been able to demonstrate that the group of interventional cardiologists are at greater risk of being affected by a certain type of partial opacification of the lens. With regard to the relationship between dose and effect, the results of our study appear to show that the higher the dose, the greater the risk and that there is no threshold dose under which there would be zero risk of opacification. However, these results do not necessarily call into question the thresholds that have just been set by the ICRP. The majority of cases of opacification that we have highlighted are, in fact, classified as grade 1 and do not cause any visual impairment. The process that results in partial opacification becoming a cataract is still not fully understood and is still being researched. It is therefore a little too early to reach a conclusion. We need more data,"* explained the researcher.



Lara Struelens and **Edilaine Honorio da Silva,**
Responsable for the Research in Dosimetric Applications unit and her colleague

An innovative dosimeter

In the meantime, the new exposure limits for the lens present a strong argument in favour of adopting effective protection measures for medical personnel. These measures include lead radiation protection glasses. These should also be paired with a dosimeter that is able to measure the exposure of the lens to radiation. The problem is that very few models of dosimeter exist at present and they have all proven to be largely incompatible with glasses of this type.

However, SCK•CEN is hoping to stand out from the crowd in this regard too. A team of researchers is working on a portable dosimeter model that is perfectly adapted for use with lead glasses and that also complies with the strict international standards that are applicable in this regard. *"Following numerous tests and calculations, we have succeeded in designing a prototype that is small and practical enough to be attached to radiation protection glasses without any loss of performance. It is currently undergoing practical testing among interventional cardiologists,"* explained Edilaine Honorio da Silva, the doctoral student in charge of the project at SCK•CEN. It may also soon be tested within nuclear power plants. If the results of these tests prove positive, the prototypes will move on to the next step: marketing.

Society

Closer to
your needs

A growth of 50% in staff numbers in some 25 years, more than a third having studied at university level, 46 nationalities, 80 PhD's: this is the result of an ambitious strategy adopted 25 years ago. Relentless innovation is the key to face societal challenges and to provide our knowledge and developments to each and every individual – citizens and professionals alike. More than ever, there is a need to communicate on the numerous assets offered by nuclear science and its diverse applications, from energy to medicine, including the environment.

Christian Legrain
Secretary-General

On the trail of ruthenium

At the end of September 2017, very low levels of radioactive pollution involving ruthenium-106 were measured in the atmosphere over Europe. Where could it possibly have come from? Armed with its expertise in the field of radionuclides, SCK•CEN, together with the IRM, embarked on a mission to trace this radioactive cloud. The conclusions of this unprecedented study were revealed in December of that same year, with a probable location.

Everyone is aware of the Chernobyl cloud which, contrary to popular belief, did not stop at the French Border. It only became too weak to be measured once past France. More recently, another pollution event, which proved to be rather mysterious, attracted a great deal of attention in the press. In late September/early October 2017, radioactive traces of ruthenium-106 (Ru-106), and to a lesser extent ruthenium-103 (Ru-103), were detected by the Comprehensive Nuclear-Test-Ban Treaty (CTBT) and certain European radioactivity monitoring networks.

"This was abnormal, since this isotope is not normally detected in the atmosphere. Ru-106 is a product of fission. Had it been the result of an accident within a nuclear reactor or a nuclear test, we would also expect to have detected caesium and radioactive iodine. Yet this was not the case. So this had to be something else. We didn't even know the origin of the pollution at that time," reminisced Christophe Gueibe, a researcher at SCK•CEN.

An interesting case

The IRSN, the French institution for radiation protection and nuclear safety, was very quick to point out that the concentrations measured *"have not had any impact on human health or the environment"*. At the same time, FANC, the Federal Agency for Nuclear Control in Belgium, confirmed that *"no increase in ruthenium concentrations had been observed in Belgium"*. Although all risk to the population had been ruled out, the mystery still remained. What kind of event could have been behind the infamous radioactive cloud and where could it have come from? These questions fascinated the researchers at SCK•CEN, who set out on the trail of this unexplained escape of Ru-106. *"This is an aspect of our role of providing information to the authorities,"* remarked Pieter De Meutter, the doctoral student behind this unprecedented study. *"However, this case is also of great scientific interest, a way to improve our knowledge of these low levels of radioactive pollution in the atmosphere, the source of which is often difficult to pinpoint".*

Christophe Gueibe and **Pieter De Meutter,**
experts in radiation

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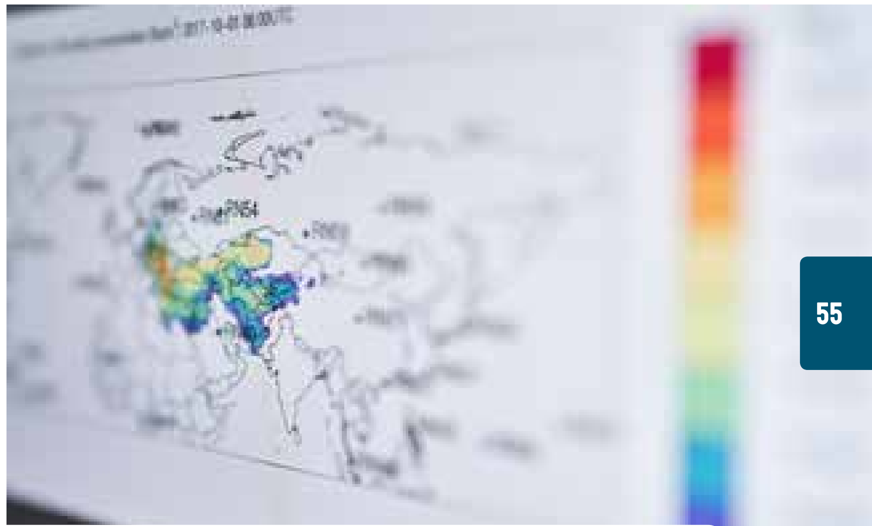
A highly probable source

Armed with data from the IMS – the international monitoring system established by the CTBT –, atmospheric transport and dispersion models and digital meteorological data from the European Centre for Medium-Range Weather Forecasts (ECMWF), researchers from SCK•CEN set out on the trail of Ru-106 in Europe and across the globe. They were assisted by experts from the Royal Meteorological Institute of Belgium (RMI).

"We attempted, in particular, to determine the source of this pollution on the basis of the stations where it had been detected, but also on the basis of those where it had not been detected. We drew up a map (see opposite), which shows the correlations between our simulations and the observations made on the ground. The weaker the values, the stronger the correlation between the simulations and the data and the more likely it became that we had located the source. There is, of course, still an element of doubt, but our calculations nonetheless reveal that the Ru-106 pollution most likely came from an area of Russia that is in fact home to several nuclear installations," explained De Meutter.

> *"There is, of course, still an element of doubt, but our calculations nonetheless reveal that the ruthenium-106 pollution most likely came from an area of Russia that is home to several nuclear installations."*



Additional information gained

However, this innovative and unprecedented study also enabled additional information to be gathered. *"We were also able to establish that the release most likely occurred between 23 and 26 September. There is no doubt that this started as a significant release, around 1 petabecquerel. This could have resulted in the application of protection measures for the local population to the applicable national standards. In any case, had an escape of this magnitude occurred in Belgium, it would most likely have necessitated the application of protection measures for the locals. We were also able to use that location as a basis for new calculations, which enabled us to evaluate the quantity of Ru-106 released into the atmosphere and to retrace its route across Europe and other parts of the world".*

This study as well as observations of the European networks confirmed that the concentrations measured in Europe were well below the level deemed to pose a risk to health or the environment.

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MYRRHA successfully tests its first fuel rods!

There are many guardian angels watching over MYRRHA. Among them, the researchers participating in the European MAXSIMA programme play an especially crucial role. Indeed, the safety of MYRRHA and its future approval are highly dependent on the results of their tests and analyses. It was against that backdrop that the very first test took place to establish the robustness of the fuel rods that will power that same reactor.

After five years of meticulous planning, the very first fissile fuel rod, similar to the model that is to be used in MYRRHA, was irradiated in the Annular Core Pulse Reactor of the Institute for Nuclear Research (ICN) in Pitesti, Romania. The aim of this test was to establish the level of energy above which deformation of the rod may occur. The results will contribute to defining the safety thresholds for the future MYRRHA reactor.

First irradiation

The Romanian research reactor is designed to withstand high doses of power over short periods of time. *"The tests that are currently taking place involve inserting a fuel rod into the reactor and exposing it to a flash of radioactivity, such as to bring about a rapid increase in the temperature of the fuel pellets in the order of around 2000°C in the space of one millisecond. The aim of the experiment is then to check the integrity of the cladding and any deformations that it may have suffered following the thermal expansion of the pellets. The idea is to check that the design of the segments that we have developed is capable of withstanding an abrupt increase in power. The ultimate goal is to establish safety margins for operation of the MYRRHA reactor,"* explained Brian Boer, researcher at SCK•CEN and member of the MAXSIMA programme.

Rémi Delville and **Brian Boer**, project managers of MAXSIMA

Results expected soon

Following on from the success of the initial test, further tests have been successfully carried out within the ICN reactor. *"We expect to carry out around ten tests in total, and 80% of those have already been completed. Everything should be finished in October 2018. The aim is to increase the amount of energy applied until we get close to or actually bring about a rupture of the cladding without causing it or its fuel cells to melt,"* added Rémi Delville.

A series of analyses are being performed on site in Romania. The fuel rods will eventually then be returned to SCK•CEN for further analysis. *"In addition to a careful analysis of the deformation of the cladding, we will check the extent to which the fuel has fragmented and expanded as a result of the increase in temperature. The results will be published in public-domain literature, as they may be of interest for Generation IV reactors, which are the subject of several projects worldwide".*

"The results will be of interest for Generation IV reactors, which are the subject of several projects worldwide."

AN IN-HOUSE DESIGN

The fuel rods being used in Romania have a special feature: they have been designed in their entirety by SCK•CEN to meet some especially stringent requirements. The tolerances set for the interior dimensions of the cladding must, for example, be below 10 microns, and those for the fuel pellets must be accurate to within a micron. The MAXSIMA project also provided the opportunity to revive a production laboratory for fissile fuels within SCK•CEN, a field in which it has long been a pioneer.

Key figures
05

820 EMPLOYEES

206 ♀ 614 ♂

36% WITH AN ACADEMIC DEGREE

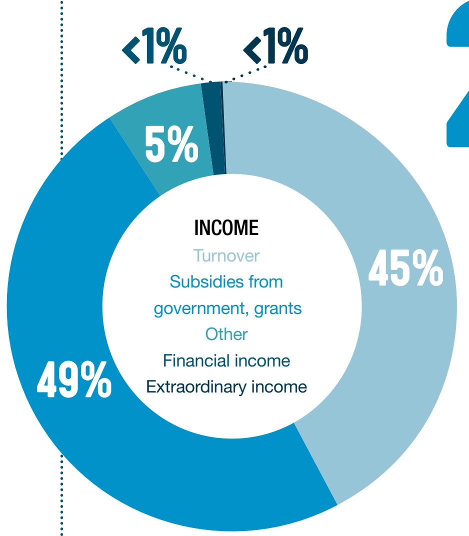
87 PHD STUDENTS

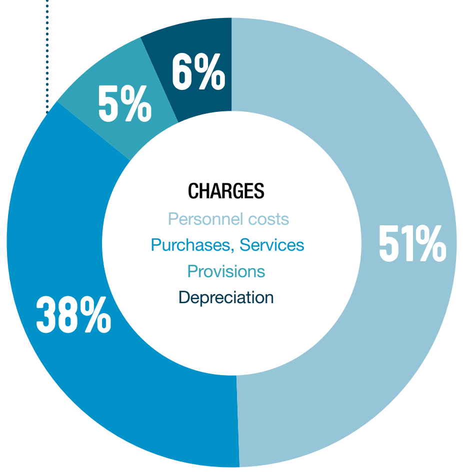
13,98 AVERAGE YEARS OF SERVICE

46 NATIONALITIES

ACTIVE IN **61** COUNTRIES

2017



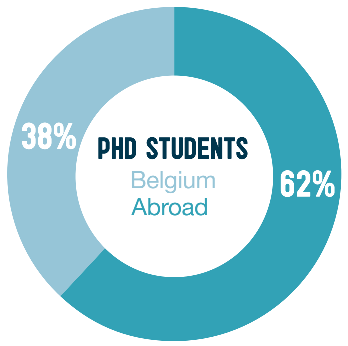


24 THESES

30 PHD STARTED

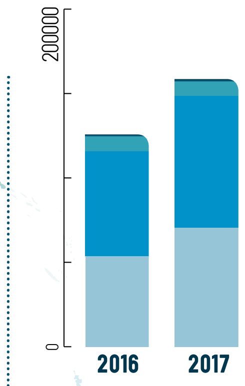
92 TRAINING FOR THIRD PARTIES

1599 PARTICIPANTS

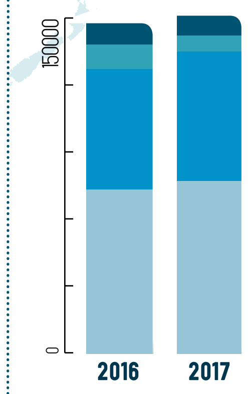


837 SCIENTIFIC PUBLICATIONS & PRESENTATIONS

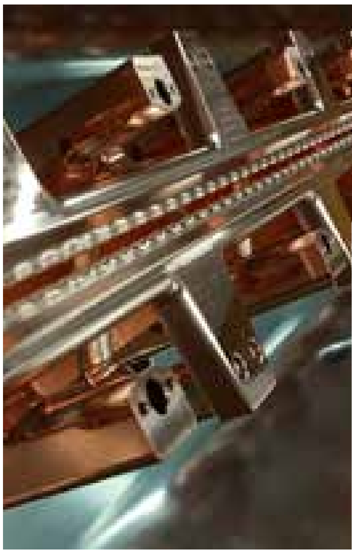
2016-2017
BUDGET EVALUATION (kEUR)

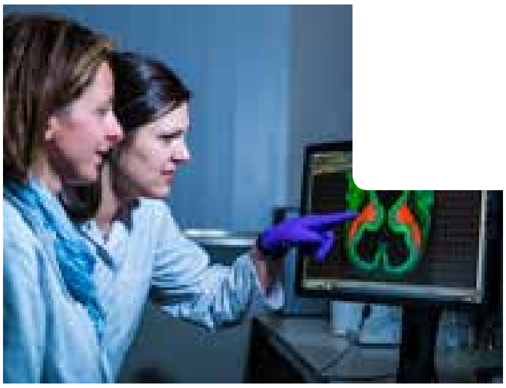


INCOME	2016	2017
Turnover	53772	70573
Subsidies from government, grants	61754	77859
Other	8988	8554
Financial income	856	1107
Extraordinary income	13	11
Total	125383	158105



CHARGES	2016	2017
Personnel costs	73277	77129
Purchases,Services	53851	57873
Provisions	10904	7255
Depreciations	9650	8867
Total	147682	151125





SCK•CEN

STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

Highlights
2017

SCK•CEN
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SCK•CEN is a foundation of public utility, with a legal status according to private law, that operates under the tutorship of the Belgian Minister of Energy.

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Publisher
Eric van Walle
Director-General

Editing
Didier Dillen
Communication expert group

Photography
Klaas De Buysser
klaasdebuysser.be
SCK•CEN photo collection

Form
Annelies Van Calster
Celine Glas
leftlane.be

Printing
Albe De Coker
Hoboken

2017

SCK•CEN

Belgian Nuclear Research Centre

65 years of experience in nuclear science and technology

As a research centre dealing with peaceful applications of radioactivity, SCK•CEN is an indispensable part of our society. We perform forward-looking research and develop sustainable technology. In addition, we organise training courses, we offer specialist services and we act as a consultancy. With more than 750 employees, SCK•CEN is one of the largest research centres in Belgium.

Throughout all of our work, there are three research topics that receive particular attention:

- Safety of nuclear installations
- Well-thought-out management of radioactive waste
- Human and environmental protection against ionizing radiation

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