highlights

2013

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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2013 highlights

Dear reader,

Experience is very valuable in our world, but the real challenge lies in making sure that the knowledge and skills built up over the years form a rich breeding ground for new views and initiatives.

This issue of *Highlights* provides some telling examples. Take our fledgling spin-off DoseVue. The driving forces behind DoseVue will launch a revolutionary system for non-invasive dosimetry close to the tumour, which allows a more targeted cancer treatment. It fits in with SCK•CEN's long experience in dosimetry and research into the effects of ionizing radiation on the body. DoseVue is not a research project, but a company. And that makes a world of difference. The creation of this spin-off reflects a new strategy in marketing our know-how.

The BR2 research reactor has been the workhorse of SCK•CEN since 1962. The aim is that all functions of BR2, including material studies and the production of medical radioisotopes and high-quality semiconductors, will be taken over by MYRRHA from 2025. Until then, we want to continue working with BR2 safely and sustainably. With this in mind, we have planned significant maintenance, including the replacement of one of the essential parts, the beryllium matrix. In this issue of *Highlights*, you can read the interesting report on the preparations.

Since its incorporation, material testing has been one of SCK•CEN core tasks. In 2013 we unexpectedly added a remarkable chapter to this long story. Our experts carried out no less than 550 tests to determine the integrity of the Doel 3 and Tihange 2 reactor vessels. This research was performed in support of FANC's decision to restart the reactors. In 2014, we will continue this research by means of an irradiation project in the BR2 reactor.

The combination of continuity and innovation is a common thread throughout 2013. Not only were there new challenges, new views and new plans, but also new faces. Towards the end of 2013, the mandate of our inspirational chairman and friend Frank Deconinck came to an end. Together with the appointment of Derrick Gosselin as the new chairman, half the board of governors has also been replaced. You must have guessed why only half; exactly, to ensure a harmonious combination of experience and innovation.

We hope you enjoy this new issue of *Highlights*.

Eric van Walle
Director-General

content

A new team

01

A dream come true

Frank Deconinck hands on the torch to Derrick Gosselin

The new board of governors at SCK•CEN was appointed in autumn 2013. A lot of new faces have joined the board. The president is also one of the newcomers. Derrick Gosselin succeeds Frank Deconinck, who for 17 years was chairman of SCK•CEN. Inside the chairman's office, in between the last removal boxes, Frank Deconinck and Derrick Gosselin talk things over after the first meeting of the new board.

Interview with
Derrick Gosselin, chairman of the board of governors and
Frank Deconinck, honorary member

> *“Nuclear research calls for a vision over at least 50 years.”*

How do you feel after your first meeting as chairman?

Derrick Gosselin: I am very much impressed with the quality of the people around the table. Each one of them is active at a high level, and what strikes me most is how much they know in many different fields. This is quite rare, but it is something I find very important. Most directors combine experience of politics and industry, or have qualifications in technology and economics. This is a team that is capable of looking at complex issues from different angles, of reflecting upon them and taking decisions about them in a thoughtful manner.

Frank Deconinck: I fully agree with what Derrick said about the expertise of the members. We are all political appointments. Political appointments: they can go in all directions, yet I believe that this board again has tremendous potential.

To what extent can a chairman put his own personal stamp on his tenure?

Frank Deconinck: I felt I could, and I hope the others didn't feel I didn't. What I found very important was the societal basis. When the PISA group was set up around social sciences, many members of the board were not convinced. If I hadn't been chairman, that group would probably never have seen the light of day.

Derrick Gosselin
'Curiosity keeps you young.'

Frank Deconinck
'The 17 years I was with SCK•CEN were the most fascinating, personally as well.'

Have you had to explain to friends or acquaintances why you opted for the nuclear industry?

Derrick Gosselin: I haven't had that question yet, but I've been answering it for five years now. Take a look at the interviews I have given over the past few years on the subject of climate change and energy policy, in which the nuclear sector will definitely play an important part worldwide during the coming years. For me, the main issue, and this is typical of complex matters, is that we lift out one vector, for instance renewable energy sources, and that by doing so think we will solve the whole problem. It doesn't work like that. What you need is a mix, a balance, and flexibility. It means you will constantly need that openness characteristic of scientific research, for the simple reason that you don't know what is happening. My specialty is exploring the future, yet I am the first to admit we can't predict the future. That is why it is important to keep your mind on it and keep taking new information into account when taking decisions.

You are conducting research in Oxford into future exploration, as well as into complex systems and turbulent environments. It seems you were destined to become chairman of SCK•CEN.

Derrick Gosselin: I was four years old when I went to the World Fair where the atom was the symbol. When I was ten or twelve, my dream was to go and work in a nuclear power plant. In those days, nuclear energy in general was the future, and the place for every young person with an interest in technology. It was the future. When I was studying for a university degree in engineering — I started as a physics engineer and finished as electrotechnical engineer — my favourite subject was physics, and nuclear physics in particular. My intention was to study nuclear engineering afterwards, but I was persuaded to study economics first. After that, I never got around to it. Becoming chairman of SCK•CEN is really a dream come true for me.

Is it the right time to hand on the torch?

Frank Deconinck: Normally speaking, we should have been replaced three years ago. I wrote a letter to the political authorities at the time, telling them that the chairman of a research centre had to be someone engaged in research or in active life. I had reached retirement age. I also made it clear that, if I were asked to continue as chairman, I would retire after three years. That is now. Secondly, I suggested replacing half the board to ensure continuity, and I also wanted more women on the board. They have heeded my request.

> *"A black hole? I haven't found it yet."*

Professor Gosselin, you are equally familiar with the academic, business and political communities. Do you feel SCK•CEN is still given its proper due?

Derrick Gosselin: We are the biggest federal research centre in the country. The fact that we have funding for MYRRHA means we have the necessary political support and backing. Otherwise it would not be possible. Clearly there are people who have the vision and intelligence to make the distinction between scientific research into the application of nuclear science, and the debates on energy policy. I believe we must make a clear distinction between those debates. For me, SCK•CEN is one of the centres paving the way for nuclear fusion. If we don't take these steps now, for instance with the research we are doing for MYRRHA, we might miss the boat. Nuclear research is something that calls for a vision over at least 50 years; fortunately we have people here in Belgium who have that vision and can defend it.

Do you feel that SCK•CEN is at a crossroads now?

Frank Deconinck: I wouldn't call it a crossroads where you still have several options to choose from. I would rather call it certain hurdles that have to be cleared. I believe we know very well what direction we want to take in scientific research. MYRRHA is clearly pointing the way. Will we get the necessary funding? That doesn't always depend on us. But a crossroads implies that you can still take a totally different direction. I believe we actually have a very clear idea of where we want to head.

Derrick Gosselin: You're right, it's not a crossroads. I believe there will be some crucial phases where SCK•CEN will become either far more important or less important, depending on the kind of political support for faster, more, or less funding. Those are the nuances.

Maybe it is too early to say, but as chairman you will probably make some shifts in emphasis, if only in view of your background as a strategy and marketing expert?

Derrick Gosselin: I am more specialized in international marketing and the strategy of innovations and technology. Marketing essentially ensures that – through exchange – you satisfy a need in a way that all parties achieve their goals. Seen from a 'political marketing perspective', so to speak, you have to make sure you have everything just right: your network, your alliances, your stakeholder management, your political message, your social grounding, your power of persuasion, and your added societal value. It all has to be right. Otherwise you won't get any more support for your investments. These insights will probably be very useful in the further development of the MYRRHA project. I also believe there is already a strong need for solutions to climate change. By using fossil fuels, we are simply burning up the basic materials for more than 7,000 products. That is not wise. We have currently reached that level of carbon emissions of which we said ten years ago: 'When we reach that point, the global temperature will rise by 3 to 4 °C.' We have reached that point, and it's still rising! We are heading for a time when we will still need nuclear technology. The problem does not lie in the long term, but in the transition to renewable energy. In Belgium, we have always been in the vanguard of nuclear technology. It would be a great pity to lose that knowledge by not continuing to invest over the long term.

On December 18, 2013 the Scientific Council (WAC) met for the first time at SCK•CEN.

From left to right: **Pierre D'Hondt, Ann Cuypers, Gustaaf Van Tendeloo, Alex Mueller, Frank Deconinck, Thomas Pardoen, Chris Huyskens, Pierre-Etienne Labeau, Michel Giot, Eric van Walle.**
Missing in the picture: **Koen Binnemans**.

Board of governors

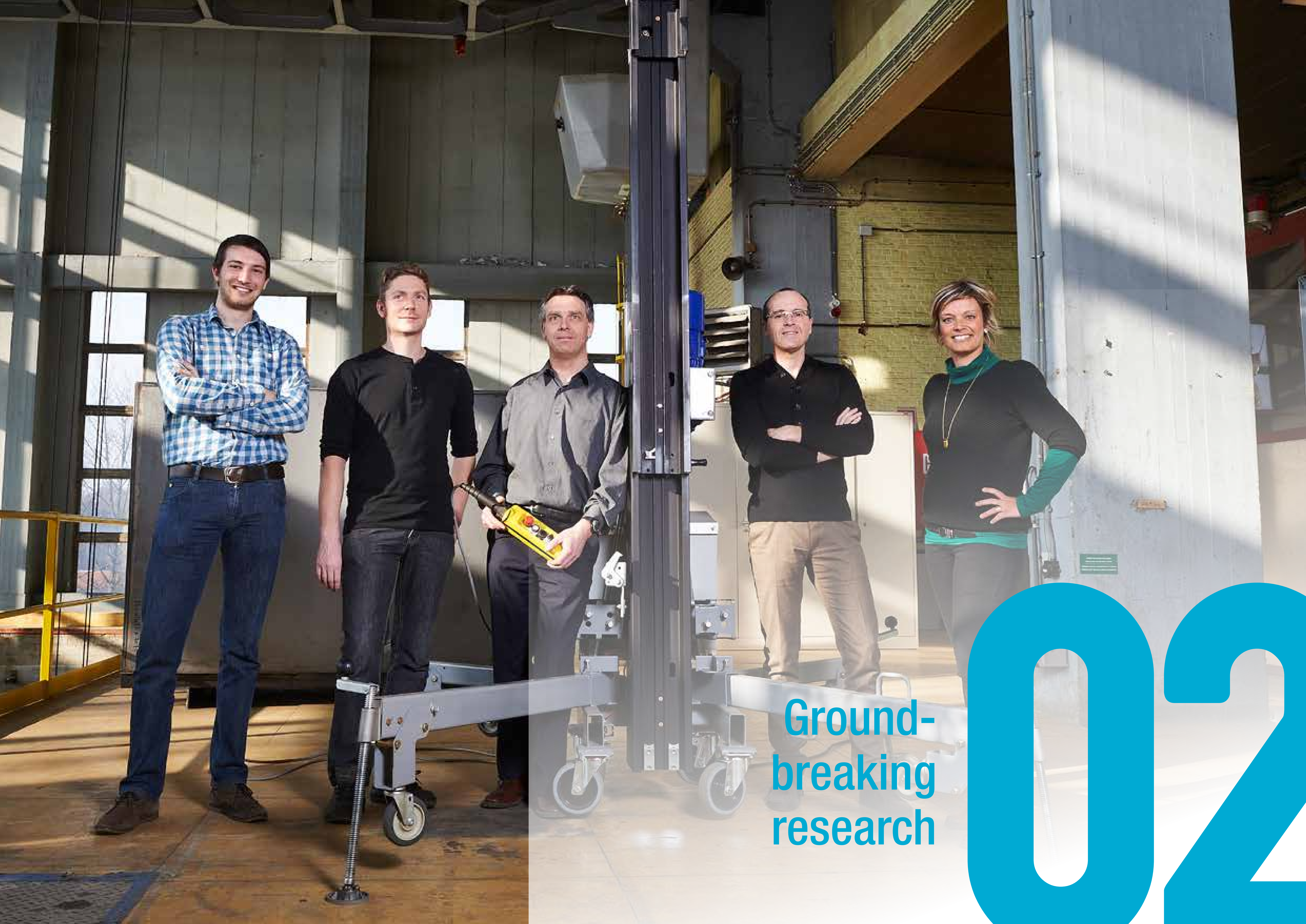
From left to right: **Catherine Spect** (Secretary), **Geert Van Autenboer** (Observer), **Frans Geerts** (Observer), **Sigrid Jourdain** (Managing Director), **Didier Hellin** (Vice Chairman), **Frank Deconinck** (Honorary Member), **Georges Denef**, **Eric van Walle** (Director-General), **Raf Suys**, **Derrick Gosselin** (Chairman), **Didier De Buyst**, **André Jaumotte** (Honorary Member), **Cis Schepens**, **Tessa Geudens** (Government Commissioner), **Michel Giot**, **Tine Baelmans**, **Katrien Kimpe**, **Nele Geudens**, **Fabrice Carton** (Government Commissioner), **Patrick Lansens** (Vice Chairman).
Missing in the picture: **Willy Legros** and **Redy de Leege** (Observer).

The last question is for the outgoing chairman. How big will the proverbial black hole be after 17 years of service?

Frank Deconinck: I must say I haven't found it yet. I won't talk about my work at the centre. That depends on what the future brings. But I'm still actively involved in hadron therapy. That is therapy using heavy particles. In France, I am a member of the *Commission Nationale d'Evaluation* that evaluates the activities of CEA (Commissariat à l'énergie atomique et aux énergies alternatives), of ANDRA – the French equivalent of ONDRAF/NIRAS – and of CNRS (Centre national de la recherche scientifique). I will be on that commission for another six years, and that's tremendously interesting. So, no black hole just yet. In any case, the 17 years I was with SCK•CEN were the most fascinating, not only scientifically, but personally as well. It goes without saying that I will pay a visit to Mol now and then.

Derrick Gosselin: You're always welcome. And you're still an honorary member of the board of governors. And that's for the rest of your life. Curiosity keeps you young. We are in an extremely privileged position, to be a part of this, to be at the forefront of one of the most fascinating research programmes of the coming years. Who else has that good fortune and privilege?

Frank Deconinck: Absolutely.



02

Ground-breaking research

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analyses of foodstuffs, animal feed and environmental samples

Frank Hardeman
Environment, Health and Safety Institute Manager

In the thousands of samples from the environment and from our food chain, we very often find radioactivity. Its origin, however, is almost exclusively natural. Uranium, thorium and particularly potassium occur pretty much everywhere and the sun also produces radioactive substances in the air. Sometimes we are able to detect radioactive substances of human origin. However, under normal operating conditions at facilities and when used correctly in medical or industrial applications, the risks are negligible.

“I didn’t know I could learn so much here”

Radiation protection experts join forces in Horizon 2020

Partly at the instigation of SCK•CEN, the various disciplines concerned with radiation protection will work together structurally for the first time in research, education and training. This is one of the main themes in which progress was made during the MELODI workshop that took place in 2013 in Brussels. Strategic research agendas were drawn up and priorities set in preparation for the European research programme *Horizon 2020*.

Interview with **Frank Hardeman**, Environment, Health and Safety Institute Manager and **Nathalie Impens**, Radiobiology

Was the scientific playing field in radiation protection so diverse before?

Frank Hardeman: In the past, research into radiation protection was strongly project-driven. There was no global vision of what had priority and what was possible within that research. Furthermore, there were limited opportunities for collaboration and additional research. Recently however, a change could be seen, as collaboration started in certain fields, networks emerged in a number of scientific disciplines, and certain groups drew up their own agendas for strategic research. All very well, but the European Commission wanted to have all those initiatives better streamlined. That happened at the instigation of SCK•CEN and a number of leading foreign research institutes.

Is the approach within the Horizon 2020 programme so different then?

Nathalie Impens: Yes. The previous seven European framework programmes were aimed at shaping the research landscape by fostering collaboration within Europe, or at boosting competitiveness. In the seventh framework programme, resources were invested primarily in thematic research projects within one discipline. The framework programmes, which ensured that within the various specialist fields a sufficiently large critical mass emerged from the European research landscape, enabled a further step to be taken in the direction of integrated research. *Horizon 2020* will now combine the specialist fields and start more from societal issues.

We have now reached a point where research can be orientated more effectively to answer questions that arise in our society. We are looking for answers to questions such as ‘What exactly is

Werner Rühm (DE, EURADOS president), **Frank Hardeman** (SCK•CEN, ALLIANCE president), **Thierry Schneider** (FR, NERIS president), **Nathalie Impens** (SCK•CEN, MELODI secretary), **Jacques Repussard** (FR, MELODI president), **Filip Vanhavere** (SCK•CEN, EURADOS vice-president), **Bruno Schmitz** (European Commission), **Michel Hugon** (European Commission), **André Jouve** (European Commission).

RADIATION PROTECTION RESEARCH

WHAT?

Radiation protection aims to control the exposure of mankind and the environment to ionizing radiation. The immediate goal is to prevent acute damage and to limit the long-term health risk to an acceptable level.

WHERE?

Research into radiation protection covers four specialist areas:

1. Radioecology: the behaviour of radioactive substances in the environment and their impact on mankind and nature.
2. Preparation for and management of emergency situations after accidents.
3. Study of and investigation into the effects of low-dose ionizing radiation (originating from the environment, accidents and medical treatments) on humans.
4. Dosimetry in industrial, medical or ecological contexts.

WHO?

In Europe, those important areas are respectively covered by the following four associations: European Radioecology ALLIANCE, NERIS, MELODI and EURADOS. Their expertise is based on a broad spectrum of scientific disciplines. Certain disciplines are needed in two or more specialist areas of radiation protection.

HOW?

Collaboration between the four associations is perfectly possible. Genetics is featured in radioecology and in low-dose research. Meteorology is an important discipline in radioecology and in preparations for emergency situations. There are many correlations between the various specialist areas. By joining forces, a substantial synergy will be achieved. It is now a question of mapping out the expertise, complementarity and common challenges.

the effect of radiation and how can we deal with it safely?' or 'What dose limits are socially responsible and acceptable?' To solve those questions, we need to look not only to the exact sciences, but to the humanities as well. This, too, is one of the new objectives of *Horizon 2020*. It means that Europe has opted resolutely for an integrated approach. Hence the change in name from framework programmes to *Horizon 2020*.

There are many associations in Europe actively engaged in radiation protection research. They must all head in the same direction. What is the role of SCK•CEN in this?

Frank Hardeman: SCK•CEN has a leadership role in the four main associations, even though these include some larger institutes. From our position within those associations, we have given a nudge in the 'new' direction. In any case, we also believe in the need to work together and to set up purpose-driven research programmes. Only then will our efforts yield the most benefit for mankind and the environment, for instance patients needing radiotherapy. The need for collaboration was especially highlighted in the MELODI workshop. Everyone hopes we are now in a transitional period; once we are properly organized, full attention can once again be on the research.

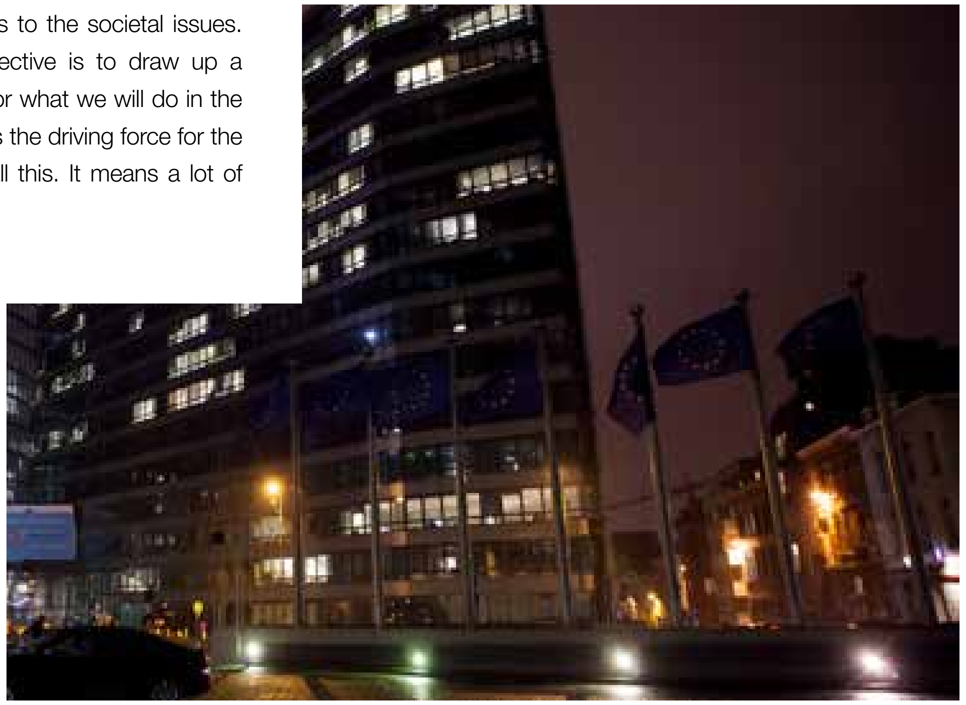
What was the difference between the MELODI workshop in 2013 and before?

Nathalie Impens: The workshop was originally focused exclusively on research into the effects of low-dose ionizing radiation on humans. In October 2013, we held the fifth MELODI workshop in Brussels, and we succeeded in transcending the boundaries between specialist fields so that knowledge can be shared more effectively. This was perfectly in keeping with the European objective. A fair amount of brainstorming went on about the common challenges and potential synergies. The finest moment of the workshop was when scientists from several disciplines told us: 'I didn't know I could learn so much here.'

A Memorandum of Understanding was signed between the four main associations. What role will SCK•CEN now play?

Nathalie Impens: The participating associations have each set an agenda for strategic research in their specialist fields as a starting point for a joint research programme in *Horizon 2020*. SCK•CEN has a coordinating role in bringing together those agendas and searching for complementary and new research areas. Experts from the different specialist fields (see page 18) can learn from each other and raise research to a higher interdisciplinary level. This should bring us closer to answers to the societal issues. The ultimate objective is to draw up a joint 'roadmap' for what we will do in the future. MELODI is the driving force for the coordination of all this. It means a lot of work for us.

The Memorandum of Understanding between the European Radioecology ALLIANCE, NERIS, MELODI and EURADOS platforms was signed by (from left to right) Frank Hardeman (ALLIANCE president), Thierry Schneider (NERIS president), Jacques Repussard (MELODI president) and Filip Vanhavere on behalf of Helmut Schuhmacher (EURADOS president) in the presence of Bruno Schmitz (Head of Unit K4 'Fission' at the Directorate General for Research and Innovation).



PROGRESS THROUGH INTEGRATION

The MELODI workshop clearly demonstrated that integration is a key factor in propelling scientific research forward. This is illustrated by two examples of the methods used to study the effect of low doses of ionizing radiation on cells and living organisms.

3D IN VITRO MODELS

For many decades, researchers were restricted to studying single cell types in monolayer cultures. However, this is an incomplete representation of the actual situation for irradiated cells. The impact on the surrounding cells, for example, is missing. Three-dimensional cell structures retain the characteristics of the in vivo tissue. As a result, three-dimensional in vitro models enable the study of cell-to-cell communication and other interactions.

INTEGRATED STUDIES ON ANIMALS DURING THEIR LIFE CYCLE

Three-dimensional in vitro cell cultures can provide valuable information. Nevertheless, in vivo studies will continue to be important for studying the effects on living creatures as a complex system over an entire life cycle. Moreover, in vivo studies are the only way to study transgenerational effects. An excellent design for life cycle studies in which several targets are integrated into the same study, such as cataract, cognitive and cardiovascular effects, was presented during the MELODI workshop. This kind of approach reduces the number of laboratory animals needed and demonstrates the complexity of the effects on living organisms.

MAIN PROJECTS

COMET

COMET (COordination and iMplementation of a pan-European instrumenT for radioecology) is aimed at strengthening and integrating the radioecology research community and setting up a joint programme in close partnership with ALLIANCE. COMET also identifies and implements complementary research themes between radioecology and preparation for emergency situations on the one hand and between radioecology and low-dose research on the other. Hildegarde Vandenhove of SCK•CEN is the coordinator, in cooperation with Nathalie Impens.

OPERRA

OPERRA (Open Project for the European Radiation Research Area) aims to put in place the structures necessary to manage the European long-term research programmes in radiation protection. The project was initiated by MELODI. There are connections with radioecology, preparation for emergency situations, and dosimetry. Nathalie Impens and Frank Hardeman coordinate the part of this project that pursues closer collaboration between the various specialist areas in radiation protection: 'We are looking for major partners for research, education and training in radiation protection. We will also set out a joint research programme.'

Both projects pave the way for the *Horizon 2020* programme and will run for four years. On 16 December 2013, OPERRA and COMET published research calls. OPERRA is only concerned with low-dose radiation research, whereas COMET intends to bring together research topics in radioecology, preparation for emergency situations, and low-dose radiation research.

Test what you eat!

Monitoring radioactivity in the food chain

Did you know that, since 2013, the total beta activity in animal feed products being exported to Belarus must be shown to be lower than 600 Becquerel per kilogram? And that SCK•CEN carries out these checks on behalf of the professional association of compound feed manufacturers in Belgium? It is just one of the many investigations that SCK•CEN conducts into radioactivity in the food chain.

The laboratories for low-level radioactivity measurements (LRM) at SCK•CEN offer a wide range of analyses of radioactivity in foodstuffs. These analyses have been performed for several years for the Federal Agency for Nuclear Control (FANC) and the Federal Agency for Food Chain Safety (FAVV). The criteria for testing foodstuffs and animal feed for radioactivity were established primarily in the aftermath of the nuclear disaster at Chernobyl in 1986. In that same year, the European Commission enacted the first set of regulations laying down the maximum permissible levels of radioactivity in various imported foodstuffs.

Fast evolving legislation

Today, nearly 30 years after that nuclear disaster, there is still post-Chernobyl legislation in place that applies to the import of certain foodstuffs. The accident in Fukushima in 2011 led to new guidelines for food testing on products being imported from Japan. Nuclear accidents such as those at Chernobyl and Fukushima have left their mark on permissible radioactivity levels which Europe and individual countries set in their legislation. What is permissible today may be outdated tomorrow. The rules are determined by safety considerations, as well as by political and economic motives. There are also big differences between types of foodstuffs: certain products have the tendency to accumulate radioactivity, for example mushrooms and red currants; and this also holds true for the animals that eat them.

Export checks

Besides the tests commissioned by the government, the laboratories also provide many services to other third parties. Industries often have conditions imposed upon them by the regulatory authorities. With SCK•CEN they have a partner to carry out radioactivity measurements. These tests mostly concern foodstuffs requiring export certification. The criteria for those checks may be highly specific. In 2013, the total beta activity in animal feed products for export to Belarus had to be shown to be lower than 600 Becquerel per kilogram. The professional association of compound feed manufacturers (BEMEFA) in Belgium took the initiative to chart radioactivity levels in compound feeds for its members in order to simplify checks. For this purpose, BEMEFA signed a contract with SCK•CEN. Quite an attractive proposition, particularly as the association numbers around 170 manufacturers representing 99% of domestic production. Today, Belarus is the only country to require such export checks. Since the laboratories have a wide range of detectors and measuring equipment, SCK•CEN was more than able to satisfy this demand. This is important, as the smooth export of Belgian animal feed products is dependent on highly reliable radioactivity analyses.

Drinking water testing

Not only food must be tested; high quality drinking water is very important as well. At the end of 2013, the revised European drinking water directive was published; a piece of legislation that had been in preparation for some time. Every Member State has two years in which to implement the directive, which sets out which radioactivity checks must be performed on drinking water. FANC coordinates the implementation of the directive in Belgium. This task will involve a whole host of additional analyses.

Implementation of the directive will take place in two phases. In the first phase, all drinking water sources will undergo a thorough analysis. In the second phase, the periodical checks may be based on so-called screening techniques using overall alpha and beta tests for which upper limits have been laid down. If the tests show that the limit values have not been exceeded, no further nuclide-specific analyses are required. If the screening values are exceeded, decision trees can help to determine which additional tests are required.

Cast-iron guarantee

Testing by screening does not give a 100% cast-iron guarantee that the total indicative dose (the essential parameter) does not exceed the limit value in all cases. This will for instance be the case with a spring of an unknown water type. In that case, screening will have to be combined with prior knowledge of the radiological properties of the drinking water.

This prior knowledge will be collected in phase 1, in which the drinking water is tested for the presence of a whole series of specific nuclides. These targeted and complex analyses will assess trace radionuclides that may be of either natural or anthropogenic origin. To perform all these analyses, specific and specially designed measurement methods are needed with nuclide-specific sensitivities. Testing will also have to be efficient and fast if large numbers of samples have to be checked.

Gamma ray spectrometry

Radioactivity testing of food is done primarily by means of gamma ray spectrometry. This technique does not involve complex sample handling, can detect large quantities of radioactive products, and provides a relatively fast determination of radioactivity levels. Radioactivity testing of food samples in the low-level radioactivity measurement laboratories is done primarily within the framework of various programmes of the Belgian agencies FAVV and FANC. Samples are usually brought to SCK•CEN, but in some cases laboratory staff also go on site to take samples.

Each year, FAVV draws up a programme for food sampling on Belgian territory, plus samples of imported foodstuffs. FANC coordinates the Belgian radiological monitoring programme, which also includes a series of food and drinking water checks.

“Industries often have conditions imposed upon them by the regulatory authorities. With SCK•CEN they have a partner to carry out radioactivity measurements.”

SCK•CEN has been carrying out these analyses for quite a few years now, and holds the necessary accreditations to do so, partly on the basis of an accreditation (ISO 17025, issued by BELAC) of the test methods.

The search for faster test methods

Besides radioactivity tests in food, the neutron activation analysis laboratory also carries out checks on food additives. The laboratory analysts check whether the concentrations of certain elements (e.g. selenium and iodine) correspond to the values cited by the manufacturers of the products. The checks consist mainly of routine tests. Where there is a general trend towards shorter turnaround times and detection limits remaining as low as possible, SCK•CEN responds to this in order to keep its services competitive. Accordingly, research is being carried out into newer and faster test methods.

Faster and less labour-intensive

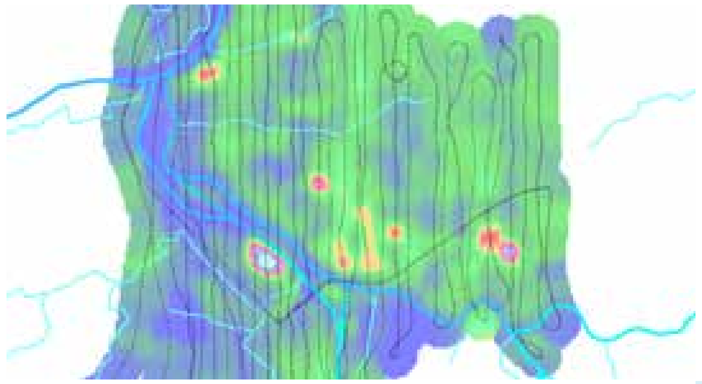
More specifically, the laboratory for low-level radioactivity measurements is investigating how the radionuclides radon-222 and radium-226 in drinking water can be determined more quickly and with less labour-intensive techniques. It is also working on methods to determine actinium-228 and lead-210 radionuclides with a sufficient degree of sensitivity, as well as on rapid test methods to determine strontium-90 in milk and foodstuffs.

Fast testing methods are particularly essential in food checks shortly after a nuclear incident. In this cases, it needs to be decided quickly whether or not a particular foodstuff can be consumed safely. In this context, the laboratories also participate in emergency preparedness exercises in which the sampling of green vegetables and the corresponding laboratory analyses are tested under conditions mimicking a nuclear incident.

Better detection for a safer world

New developments that give a clear picture of radioactivity

Controlling nuclear crises and supporting the community efficiently require being able to measure radioactivity levels quickly and accurately. SCK•CEN makes its contribution by developing techniques to detect radioactivity more effectively. Measuring radioactivity over a large area, and filtering out interference from xenon on readings are two closely related examples.



After a nuclear accident, radioactivity levels over a large area need to be determined quickly. As a partner of the government in nuclear emergency preparedness, the Interior Ministry provided SCK•CEN with the necessary instruments to detect radioactively contaminated areas from the air by helicopter.

Following the accident in Fukushima, such large-scale measurements were carried out in a short time. SCK•CEN realized that data from the International Monitoring System (IMS) of the preparatory commission of the Comprehensive nuclear Test-Ban Treaty Organization (CTBTO), a system that was developed for the detection of nuclear tests, can also have considerable added value for nuclear emergency preparedness.

With this in mind, the Belgian Nuclear Research Centre, in partnership with the Federal Agency for Nuclear Control (FANC) and the Royal Meteorological Institute (KMI), took the initiative to set up a National Data Centre. Its purpose is to analyse the data from the IMS and to advise the Belgian authorities. A fine combination of two themes: organizing nuclear emergency preparedness, and contributing to a world without nuclear weapons.

Aerial gamma ray spectrometry

High detection sensitivity within a short measurement time is essential to identify large contaminated areas. It enables equipment set up in a helicopter to cover a large area quickly. SCK•CEN uses large-volume detectors (4 detectors, each with 4 litres of thallium-doped sodium iodide crystals). Within a few seconds they can collect sufficient statistical data to determine the level of contamination, with both identification of the radionuclides and determination of their activities. This technique is called aerial gamma spectrometry (AGS).

Does the equipment function in a helicopter? Is the collected data interpreted correctly? And how can this data be best represented spatially? These were the big challenges facing the researchers.

Favourable test

After a whole series of tests and software updates performed in cooperation with the manufacturer of the AGS system, the equipment was found to be sufficiently reliable. In 2013, SCK•CEN made a first test flight with a helicopter. It took barely fifteen minutes to set up the measuring equipment in a helicopter belonging to a private firm. This is important in real incidents. The measuring equipment was then tested in a three-hour flight over an area of 100 km² with limited historical contamination. It proved highly sensitive, even in areas with very low contamination. A positive result!

The equipment is not only ideal for taking readings after a nuclear accident; it may also prove valuable for radioactivity measurements in the environment for the purpose of gaining a better idea of historical contaminations. In fact, a number of previously unknown areas with slight historical contamination were discovered during the test flight.

“It took barely fifteen minutes to set up the measuring equipment in a helicopter from a private firm; this is important in real incidents.”

Rolling terrain

Researchers at the Belgian Nuclear Research Centre will soon run tests to allow a more accurate interpretation of the impact of altitude on the results. They will also examine the impact of strongly undulating terrain on the results. For teams from the US Department of Energy, this was one of the most complicating factors when measuring the contamination in Japan following the Fukushima accident. This study is very valuable in Belgium, as the Tihange nuclear power plant is situated in the Meuse valley, surrounded by hills. SCK•CEN is also looking into how best to deploy the equipment in emergency situations and emergency preparedness exercises.

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Xenon equals interference

The performance of the International Monitoring System relies on the accurate measurement of radioactivity. Is the system capable of detecting a nuclear test? This will depend on the sensitivity of the measuring stations and the geographical distribution of the stations across the globe. The main indicator of an underground or atmospheric nuclear test is radioactive xenon. But there is one problem: worldwide interference from background radioactive xenon is so strong that it diminishes the sensitivity of the network.

Xenon is a noble gas made primarily by a small number of producers of medical radioisotopes for nuclear medicine. Their xenon emissions prevent accurate measurements. Can emissions of radioactive xenon be limited? If so, that would substantially improve our ability to detect nuclear tests.

Filtration

To answer that question, SCK•CEN went in search of efficient methods and materials to filter out radioactive xenon. The project, funded by the European Union, is in support of the Comprehensive nuclear Test-Ban Treaty Organization (CTBTO). Researchers at SCK•CEN are currently building a prototype installation to test a reduction of xenon emissions at the Institute for Radioelements (IRE), one of the leading producers of medical radioisotopes. This is technology that may be useful anywhere in the world, especially in countries neighbouring nations that are engaged in unlawful nuclear activities.

Worldwide application?

If the project for reducing xenon emissions is a success, the technique may be extended to several medical radioisotope producers worldwide. This would really help to diminish the worldwide background xenon level. The experience gained in this way may also be used to enhance the sensitivity of the xenon measuring stations in the International Monitoring System, for instance by filtering out radioactive xenon from the air more efficiently, particularly after a nuclear test or nuclear incident.

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BEST PRESENTATION

The 'EU European Star Award 2013' for the best presentation on a topic that may improve the verification of nuclear tests was awarded to SCK•CEN during the CTBTO Science and Technology conference in Vienna.

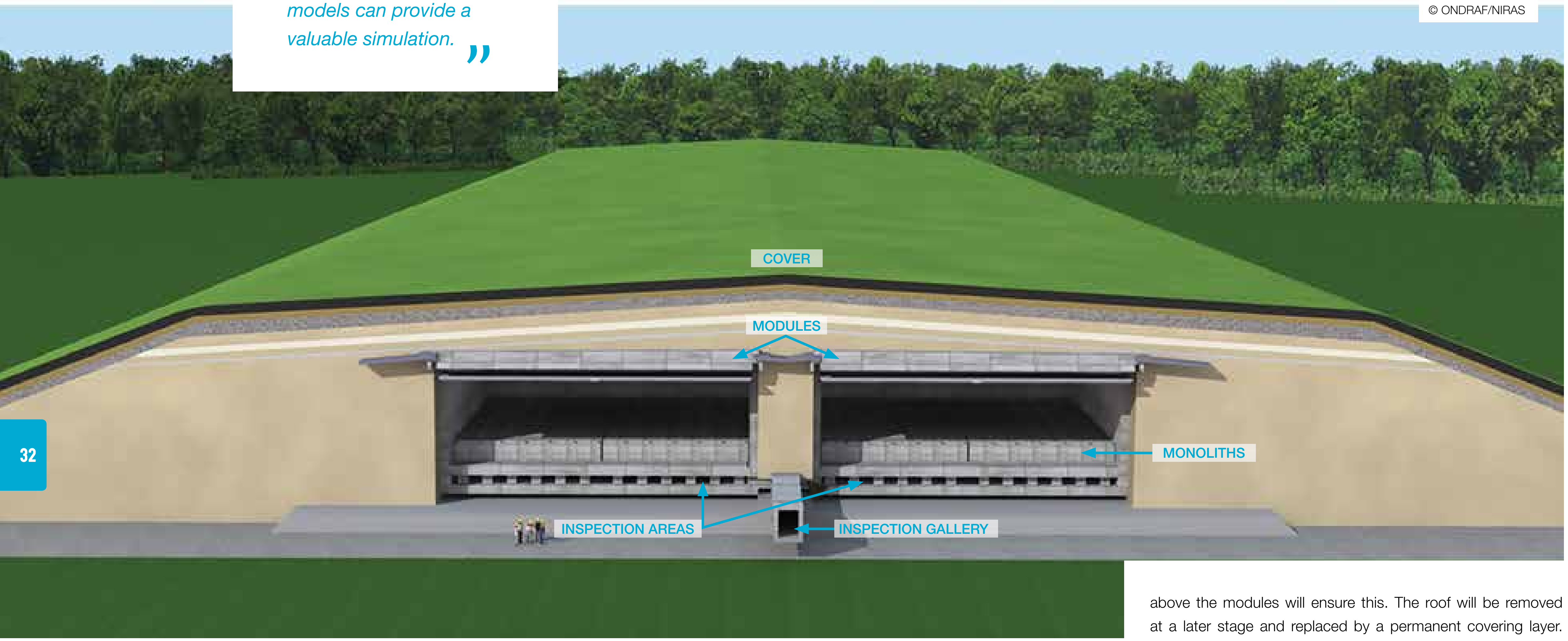
Surface disposal of low-level and medium-level short-lived waste

How safe is the disposal facility in Dessel in the long term?

A disposal facility for low-level and medium-level short-lived waste will be built on a site situated in Dessel. The facility will consist of 34 modules, which corresponds to a storage volume of approximately 70,000 m^3. The waste containers are encapsulated in a concrete box which is filled with mortar. Approximately 900 of these blocks, or monoliths, fit inside each module. Such an imposing facility as this is only possible after an equally impressive study.

On 23 June 2006, the authorities decided to store low-level and medium-level short-lived waste – category A waste in short – in Belgium in a surface disposal facility in Dessel. ONDRAF/NIRAS, the Belgian Agency for Radioactive Waste and Enriched Fissile Materials, must submit a safety study to the Belgian Federal Agency for Nuclear Control (FANC) in order to obtain a construction and operating permit. It goes without saying that safety is the overriding parameter when it comes to planning and constructing a facility such as this. A team of researchers from SCK•CEN is working on the evaluation of the long-term safety and the fundamental science underlying this study.

> *Nobody can look into the future, but computer models can provide a valuable simulation.*



Safety above all else

Safety is the highest priority for this project. In order to evaluate safety, the characteristics of the disposal facility need to be described in detail. It will not only store the waste, but also shield it from the environment. In addition, the precise characteristics of the stored waste products at the time of disposal need to be known. And finally, surveillance and monitoring of the facility will be indispensable in order to guarantee safety.

Surface disposal

The category A waste facility in Dessel is a surface disposal facility. This means that it will be built above ground. The installation is, therefore, in direct contact with the biosphere, and the safety evaluation must take into account the effect of future developments at the site, e.g. earthquakes, erosion and climatic changes.

Water barrier

Water seeping into the facility is the main way in which the waste radionuclides could be dissolved and then transported outside the facility. It is crucial to avoid any water infiltration during the initial operating phase (~ 50 years). A steel roof above the modules will ensure this. The roof will be removed at a later stage and replaced by a permanent covering layer. The performance of this layer will be followed up meticulously in such a manner that any water infiltration can be minimized for yet longer periods.

A covering layer made from natural materials constitutes a first barrier against long-term water infiltration. The biological top layer (with vegetation) maximises evaporation from above. A stone layer in the middle of the covering protects the underlying compacted clay layer from plant roots and burrowing animals. The clay layers, underneath the cover, have low permeabilities. An impermeable concrete sheet is then placed on top of the storage modules. The various natural covering layers and the large quantity of concrete on top of the module, including the monolith itself, guarantee minor water infiltration in the facility for the longest period possible (several hundred years).

Solid monoliths

Monoliths offer even more advantages. Thanks to the concrete shielding, they are safe to work with. The concrete also slows down the migration of radionuclides, thanks to the chemical bonding with the minerals in the cement. The thick concrete base of the module is underneath the monoliths which, in turn, results in a slow migration. The entire disposal facility will be built on a sandy soil and a sand-cement layer, sufficiently high enough above the water table that water cannot enter from below.

Study into the effect of nuclides

Over time (hundreds to thousands of years), a fraction of the radionuclides which have not yet completely decayed inside the facility, will slowly migrate via the groundwater. This migration is an important aspect which will determine the radiological impact of the disposal facility. The main ways in which groundwater reaches the biosphere and mankind are via extraction wells, rivers or simply via rising water. SCK•CEN researchers have made different computer models which confirm that the radiological impact is small compared to the dose people are subjected to from natural radiation, and that in all cases, the legal dose restrictions are complied with.

"SCK•CEN will contribute to finding answers to FANC's additional questions."

A several metres high file

An extremely detailed and comprehensive application file is required in order to request a permit for a category A waste facility. SCK•CEN contributed substantially to ONDRAF/NIRAS's safety file, especially concerning those aspects related to long-term safety. The researchers' main role was to provide scientific support for discussions concerning safety. They transformed phenomenological knowledge and possible evolutions in the disposal facility into numerical models which enabled thorough safety calculations to be performed. SCK•CEN provided important information about the flow of water through the covering, the chemical bonding of radionuclides to concrete, the biosphere characteristics, the geology of the site and the possible consequences of future climate changes.

Calculate and simulate

Nobody can predict the future, but it is possible to make valid simulations using computer models. The covering layers were designed very carefully, using numerical simulations and experimental data to optimise the composition, in order to minimise water infiltration. The concrete barriers are one of the most important elements regarding long-term safety of the surface disposal facility.

How did the team at SCK•CEN approach the study? The first step to demonstrate long-term safety is to gather, select and document the existing data and knowledge. There is a huge amount of data relating to the physical and chemical properties of concrete. Because the concrete comes into contact with the environment, its properties will change gradually and it will therefore contribute less and less to the safety of the facility. This evolution has been studied on a geochemical basis and by using simplified models.

To assess uncertainties about any future developments and the evolution of the facility, numerous scenarios were considered and safety analyses were carried out. They demonstrate the safety margins associated with any radiological consequences.

In cooperation with ONDRAF/NIRAS and other partners, a team at SCK•CEN has developed scenarios to assess the impact of the properties of the different components, and their evolution, in the installation in terms of security and operational reliability. The hydrogeological conditions have been studied using numerical simulation to model the groundwater. A regional model over a large-scale was also built, with its own extensive experimental network. And finally, the processes taking place in the biosphere have been analysed, and much associated data collected.

The permit procedure for the disposal facility in Dessel is a stepwise process. In January 2013, ONDRAF/NIRAS presented the results of more than six years of research to FANC, which will ask a number of additional questions regarding this file.

More research expected

In the next phase, SCK•CEN will contribute to finding answers to FANC's additional questions, within the context of obtaining the permit for the disposal facility. At that time, a new phase of the research, development and demonstration programme for the ONDRAF/NIRAS surface disposal facility will be launched. SCK•CEN can play a further part in this phase by trying to minimise any uncertainties and thereby reinforcing trust and confidence in the long-term safety.

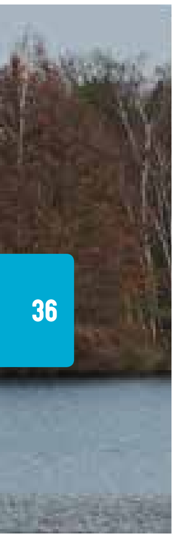
In addition, a long-term experiment over 30 years is planned for the final covering. In this study, SCK•CEN would study aspects such as percolation, stability, permeability and chemical variables.

The interaction of the concrete with different environments, as well the theoretical and experimental work on this, will be an important issue in the future. Currently, three PhD students at SCK•CEN are studying the microstructural evolution of concrete when it comes into contact with an environment other than concrete. They are also carrying out experimental work on the degradation mechanisms of concrete, and scaling up laboratory and microstructural information to the real scale.

From nuclear installation to greenfield site

SCK•CEN develops a new measurement method

How do you dismantle a nuclear facility to the point that only greenfield land remains? Essentially this can only be achieved by first accurately measuring the radioactivity in equipment and buildings, and then removing these according to best practice whilst creating the least possible waste. A new measurement method uses on-site gamma ray spectrometry, in combination with modelling. The results make it easier to direct the flow of demolition materials properly.



The decommissioning of nuclear facilities is usually a consequence of reaching the end of their life cycles. This end may be the result of an economic or political decision, or even an incident. It may involve the equipment, the building in which it is housed, or the site as a whole. In other words, everything that is classified and licensed as nuclear. Often the intended final outcome of the decommissioning process is a greenfield site; the site is restored to its original condition before the nuclear facility was built.

For the removal of such materials, the National Institute for Radioactive Waste and Enriched Fissile Materials (ONDRAF/NIRAS) has established qualified procedures based on strict acceptance criteria. For instance, it is very important to determine the activity concentrations of the radionuclides that are present. Nevertheless, most of the materials are neither contaminated nor activated, and eventually finish up being treated as standard industrial waste. This process, too, complies fully with Belgian law. Naturally there must always be proof that any activity concentrations are below the limit values defined by law.

Determining concentrations

To ensure a smooth and targeted removal of radioactive waste and any released materials, reliable and efficient measuring systems and methods are needed to determine activity concentrations. This is not limited to a final inspection of the materials produced. Robust processes are based on an extensive and qualitative on-site measuring programme prior to demolition. Gamma ray spectrometry is used to determine which radionuclides are present as well as their activity concentrations. This is followed by intermediate checks and eventually a final inspection. The *Decommissioning and Decontamination* unit at SCK•CEN seeks to develop and optimize reliable measurement methods for all these stages.

> *“The new method gives results for the entire surface area, not just for a few locations.”*

Wide scope

The unit is engaged primarily in the decommissioning of BR3 (Belgian Reactor 3), a pressurized water reactor. This is the same type of reactor as the commercial reactors built up in Belgium. The group is also involved in other projects, such as the decommissioning of the Belgonucleaire MOX plant and the Thetis research reactor at the Nuclear Science Institute at Ghent University.

For many of the applications, the unit uses measuring devices for on-site gamma ray spectrometry, in combination with modelling. This measurement technique has a wide range of applications, and the experts at SCK•CEN have a great deal of experience with it. The measuring device, therefore, is used not only for regular measurements in comparable internal and external SCK•CEN projects, but also for projects that are not necessarily connected with decommissioning. Examples include the isotopic determination of MOX and the analysis of activation products from the irradiation of silicon in reactors BR1 and BR2.

New measurement method is more accurate

How much material has to be removed from a radioactively contaminated room? On the one hand, the remaining structure has to be clean; on the other hand, we want to try and keep the volume of radioactive waste as small as possible. More specifically: What is the depth to which a concrete structure has been contaminated by caesium-137 (an unstable radioisotope of caesium)? The answer to this question is important when preparing decontamination work.

The conventional measurement method consists of taking drilling samples from several locations, slicing them, and then breaking and grinding them. The resulting powder sample is then characterized radiologically. This is a time-consuming task, and only gives results for those specific locations, which may not even be representative of the entire surface area.

With this in mind, the *Decommissioning and Decontamination* unit developed a new measurement method using on-site gamma ray spectrometry, followed by geostatistical interpretation of the measurement results. The new method has the advantage that it does not damage the concrete and that large surfaces can be measured relatively quickly. Above all, it gives results for the complete surface area, not just for a few locations.

Of course it is not always easy to reach every place in a facility. In 2013, to remedy this problem, the group designed mobile structures – a modular elevator – to position the measuring equipment easily. A fair amount of engineering was required; proof yet again that decommissioning is a multidisciplinary operation.

European research

The development of the measurement method to determine depth contamination will evolve considerably in the future, as a partnership is planned with other European research institutes in the MetroDECOM project. Specialists will compare different measurement techniques and optimize the use of statistical methods. The project will also focus on the further development of on-site measurement methods for the final inspection of buildings.

03 High-performance reactors

Leo Sannen
Nuclear Materials Sciences Institute Manager

SCK•CEN conducted hundreds of tests on materials representative of the Doel 3 and Tihange 2 reactor vessels. From all angles the indications of flaws in de pressure vessels were studied. The potential impact on the integrity and the safety was thoroughly analysed.

550

550 tests for Doel 3 and Tihange 2

Until the puzzle fits together

Major overhaul of BR2 reactor requires accurate calculation of core elements

Interview with **Steven Van Dyck**, BR2 reactor manager and **Michael Källberg**, Experimental Rig Design

The commissioning of the MYRRHA reactor is scheduled for 2025, which means that BR2 still has to last a while. For five decades now, it has played a pioneering role in research into applications of nuclear technology for power generation and in the medical sector. The time has therefore come for a third major overhaul. And for an interview on the subject with Steven Van Dyck and Michael Källberg.

Is the BR2 reactor still so interesting that it has to last for at least another ten years?

Steven Van Dyck: BR2 is the biggest and most flexible materials testing reactor in Europe today. Because of developments in the use of the reactor, the possibilities of the equipment, and the potential for future applications, BR2 continues to make an essential contribution to the short- and medium-term goals of SCK•CEN. Did you know that the reactor supplies 20 to 25% of the annual worldwide demand for radioisotopes for medical and industrial applications? A considerable proportion of the global production of high-grade semiconductors for (renewable) energy applications in the shape of neutron-doped silicon is produced in BR2 as well. It contributes to research projects to enhance the safety of existing and future nuclear reactors, as well as to the development of materials and technologies with a reduced risk of proliferation of nuclear weapons.

So a modern nuclear research centre still needs a high-performance irradiation facility.

Steven Van Dyck: Yes, BR2 is and remains such an infrastructure. The purpose of this third major overhaul campaign is to guarantee the correct operation for at least the coming period, and to bridge the gap to the start-up of the MYRRHA facility.

Michael Källberg: BR2 has been in operation since 1961, which is more than five decades!

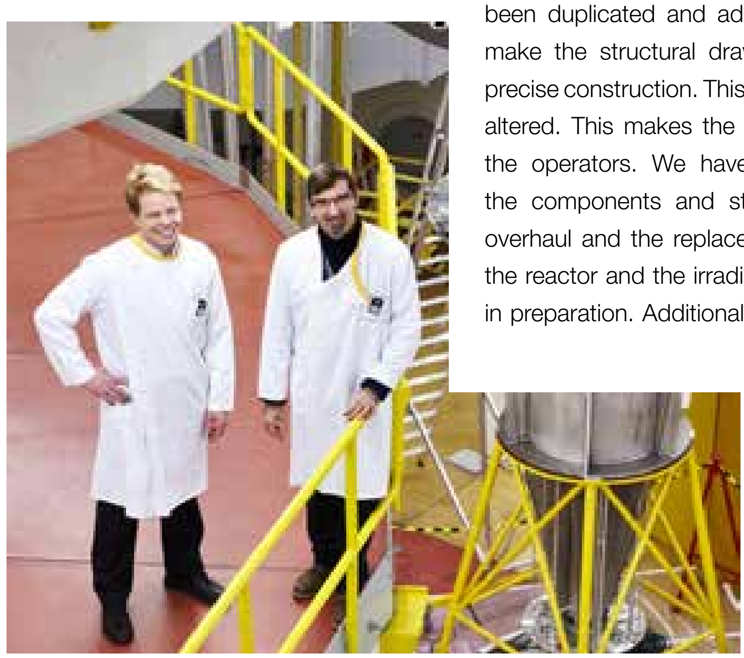
Replacement of beryllium core

What is the starting point for the maintenance project of the BR2 reactor?

Steven Van Dyck: The project is based on a systematic analysis of the risks, taking into account the ageing of the installation, changing regulations, and the demand for new applications. Based on this analysis, we are investing substantially to ensure that BR2 can continue to fulfill its role from 2016 to 2026 within the applicable safety standards. There is one maintenance operation that is the most important of all.

Which is?

Michael Källberg: The replacement of the beryllium core of the BR2 reactor. That core has a legally stipulated maximum useful life. Beryllium has a limited lifespan of around 15 years as it begins to deform under the effects of irradiation. Although we have not yet reached the limit, the lifespan of the beryllium currently in the reactor does not extend to 2026. For that reason we have opted for preventive replacement, which will allow a more intensive and more flexible use of the reactor. In this way, we can cater to the changing and growing demand for irradiation services.



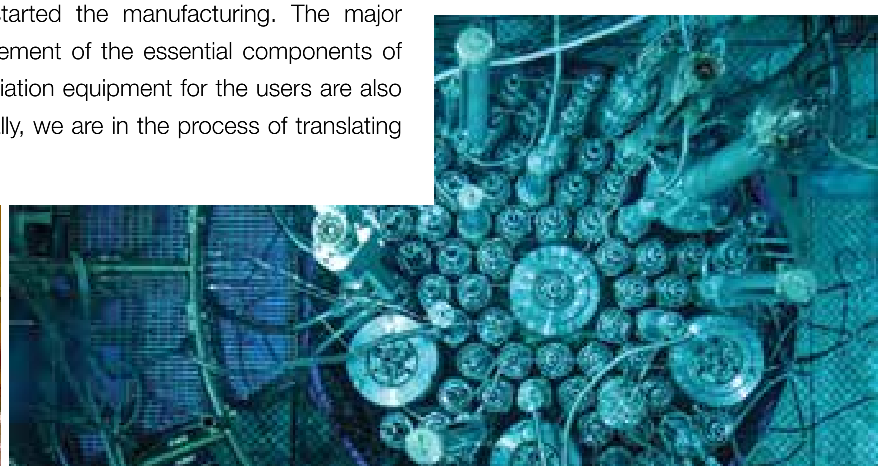
Why is the core made of beryllium?

Steven Van Dyck: The complex geometry of the reactor core is designed for maximum accessibility to a compact high-performance core. This is made possible by using beryllium as building material for the central part. This very light metal, which absorbs few neutrons, allows us to manufacture a much more compact reactor core, compared to a water or graphite filled reactor.

Michael Källberg: The reactor channels have a hyperbolic paraboloid structure. Each channel is made of a stainless steel top part with cooling holes through which the water can flow to the fuel whilst experiments can be positioned in the middle. There the channel is made of beryllium, a very light metal. Underneath the beryllium core there is another stainless steel part with cooling holes to the outside. The parts are held together by conical keys.

The reactor core had already been replaced in 1979 and 1996. Are there any lessons to be learnt from that?

Steven Van Dyck: The original design of the reactor core has been duplicated and adapted to modern design methods to make the structural drawings for the present and extremely precise construction. This reduces the risk of having components altered. This makes the operation safer and more efficient for the operators. We have also updated the specifications of the components and started the manufacturing. The major overhaul and the replacement of the essential components of the reactor and the irradiation equipment for the users are also in preparation. Additionally, we are in the process of translating the conclusions of the stress test for BR2 into measures to further improve the safety of the facility, even under extreme external conditions such as earthquakes.



Drawings from 1978

Michael Källberg: During the last overhaul, drawings were used based on drawings made in 1978 by the firm LaMeuse. The entire matrix was replaced in 1978 and the reactor was started again from scratch, just like we are doing now. In 1996, the elements of the zero power model of BR2 were recycled, and only a few new components were purchased. That is why we decided to take the structural drawings of 1978 as a reference. But are those drawings totally accurate? To find that out, we started with new 3D drawings. It was not our intention to make changes to the original design.

And were the drawings right?

Michael Källberg: I discovered that the advanced hyperbolic puzzle of hexagons did not really fit together perfectly! In 3D CAD software, the surfaces must be really parallel. In the nineteen fifties, a team of thirty draughtsmen would spend almost a whole year on the calculations. People make mistakes, and therefore those drawings lacked precision here and there. When I let the computer work from those drawings, the pieces did not fit. I was therefore obliged to go back to the fundamental definition of the matrix design, the definition of hyperboloids. Now we have been working on the design with four CAD engineers for five months, and the job is done!

> *"Did we or the draughtsmen back in 1978 make a mistake?"*

You mentioned paraboloids and hyperboloids. What do they look like?

Michael Källberg: Take, for instance, a bundle of twisted toothpicks. Each toothpick has a hexagonal shape and touches its neighbour just 0.0254 mm apart. To get that exact ratio, each hexagon has to be slightly distorted. The distortions are dependent on the gradient of the channels, which in turn depends on the distance from the centre of the core. This gigantic puzzle was described in inches on the drawings. A typical measurement on the drawings was 3.790 inches, which converts to 96.266 mm. The mathematically correct measurement, however, is 96.234 mm, which is a correction of 0.032 mm. Well, such a toothpick no longer fits the model. In actual fact, though, those minor differences will be smoothed away in the production tolerances. But to check the hexagons in the CAD system, we used the geometric calculations to more than ten decimal place accuracy. The old drawings were then compared to the new ones. Was there a difference? Then we checked: did we or the draughtsmen back in 1978 make a small mistake?

Start at end of 2014

Is beryllium dangerous to work with?

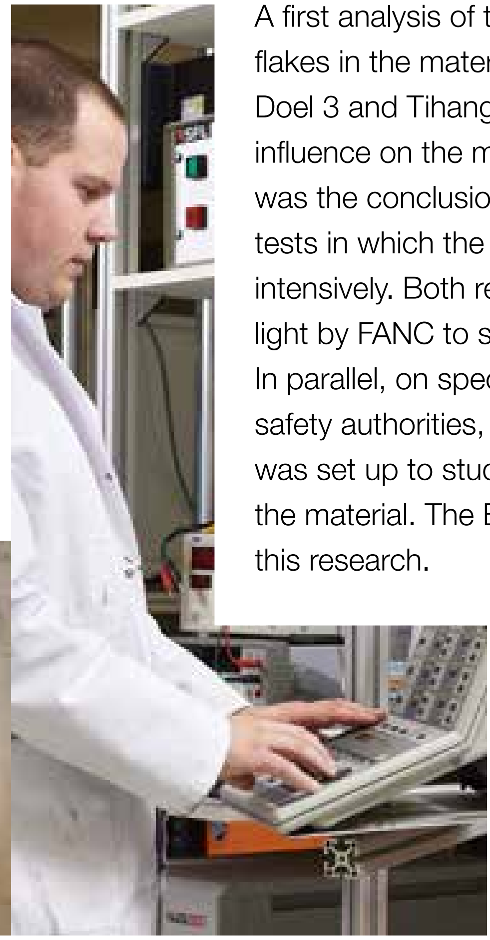
Michael Källberg: Yes, you have to watch out! Beryllium metal is relatively harmless, but beryllium oxide is toxic and dangerous if you inhale the dust. Mechanical processing of beryllium where dust and oxide may be generated is therefore a high-risk operation and somewhat similar to working with asbestos. There are only three countries in the world that supply beryllium: the United States, China and Kazakhstan. This means there are not many companies that can produce beryllium with the requisite high tolerances. So we had to choose two manufacturers: one for the stainless steel components and another for the beryllium. At SCK•CEN we assemble and test the components in a copy of the reactor. There we can assemble the matrix and check whether all the parts fit together before placing it in the BR2 vessel.

How long will it take to replace the reactor core?

Steven Van Dyck: More than a year starting from the end of 2014. In the run-up we will be busy making technical preparations and replacing other parts of the installation. In the spring of 2016, the new reactor core will be tested to make sure it is equivalent to the present core. By mid-2016, the facility will be available once more to provide essential scientific services for the next ten years.

550 tests to support Tihange 2 and Doel 3 integrity assessment

Extensive research based on SCK•CEN's long-term expertise



A first analysis of the impact of the hydrogen flakes in the material of the reactor vessels of Doel 3 and Tihange 2 shows no significant influence on the mechanical properties. This was the conclusion drawn after more than 550 tests in which the SCK•CEN experts participated intensively. Both reactors were given the green light by FANC to start up again and run one cycle. In parallel, on specific request of the Belgian safety authorities, an interim research programme was set up to study the effects of irradiation on the material. The BR2 reactor will be engaged for this research.

Nuclear installations in Belgium are thoroughly inspected, which is legally required. During an extensive ultrasonic examination of the reactor vessel of Doel 3 in June 2012, a large number of hydrogen flakes were found. These hydrogen flakes are known to occur when the thermal treatment of the reactor vessel during manufacturing is not performed completely correctly. Identical findings, to a lesser extent however, emerged during the inspection of the reactor vessel of Tihange 2. This was expected, as both vessels were made at about the same time, in the same way and by the same manufacturer.

Integrity assessment

The Federal Agency for Nuclear Control (FANC) asked the operators of Doel and Tihange to evaluate the integrity of the reactor vessels, as required in such situations by the current standards and codes. To assess the vessel integrity, the properties of the material have to be determined. The operators called upon the expertise of SCK•CEN to start up a test programme. SCK•CEN has in fact always carried out the reactor pressure vessel surveillance programmes of the Belgian nuclear power plants and can boast extensive international experience in this field.

Three phases

SCK•CEN was initially involved in the material test programme to assess the mechanical properties of the reactor vessel. As no irradiated material was available and as it is impossible to use material from the vessel, the assessment was performed on a non irradiated

"SCK•CEN has always carried out the surveillance programmes of the Belgian nuclear power plants and can boast extensive experience in this field, both nationally and internationally."

representative material containing a lot of hydrogen flakes. The impact of irradiation was evaluated based on the measured chemical properties of the material. The hydrogen flakes are indeed closely connected to the presence of the 'macrosegregation zone', a zone enriched in impurities and alloying elements which occurs during solidification. For the test programme, the investigators used three blocks of material in consecutive phases.

Given that hydrogen flakes are parallel to the reactor vessel wall (quasi-laminar), they examined in the first phase the Doel 3 spare surveillance material in order to check the effect of specimen orientation on the fracture properties of the vessel material. In the second phase, the effect of macrosegregation on the mechanical properties of the vessel material was evaluated. For this purpose, the Doel 3 nozzle cut-out (a remainder from the construction of the reactor vessel, see page 45, centre picture) was used. The third phase consisted of the examination of a material containing hydrogen flakes that was supplied by France and that can be considered as representative of the vessels of Doel 3 and Tihange 2. The purpose was to find out how the material surrounding the hydrogen flakes is affected by their presence.

Little impact

The more than 550 tests led the investigators to conclude that the effect of the presence of hydrogen flakes on the mechanical properties was very limited. To assess the behaviour after irradiation, the slightly enriched chemical composition in this zone, i.e. the increased presence of zinc, copper and phosphor, has been considered according to globally validated assessment formulas. All the tests show that the presence of hydrogen flakes has a limited impact on the fracture behaviour of the material.

Authorization for one year

FANC gave permission for an operating cycle of about one year for both nuclear reactors, pending to some additional investigations. To that end, the investigators of SCK•CEN will conduct an experiment in 2014 in the BR2 reactor to assess the effects of irradiation on the French test material containing hydrogen flakes, in order to verify the abovementioned assessment formulas.

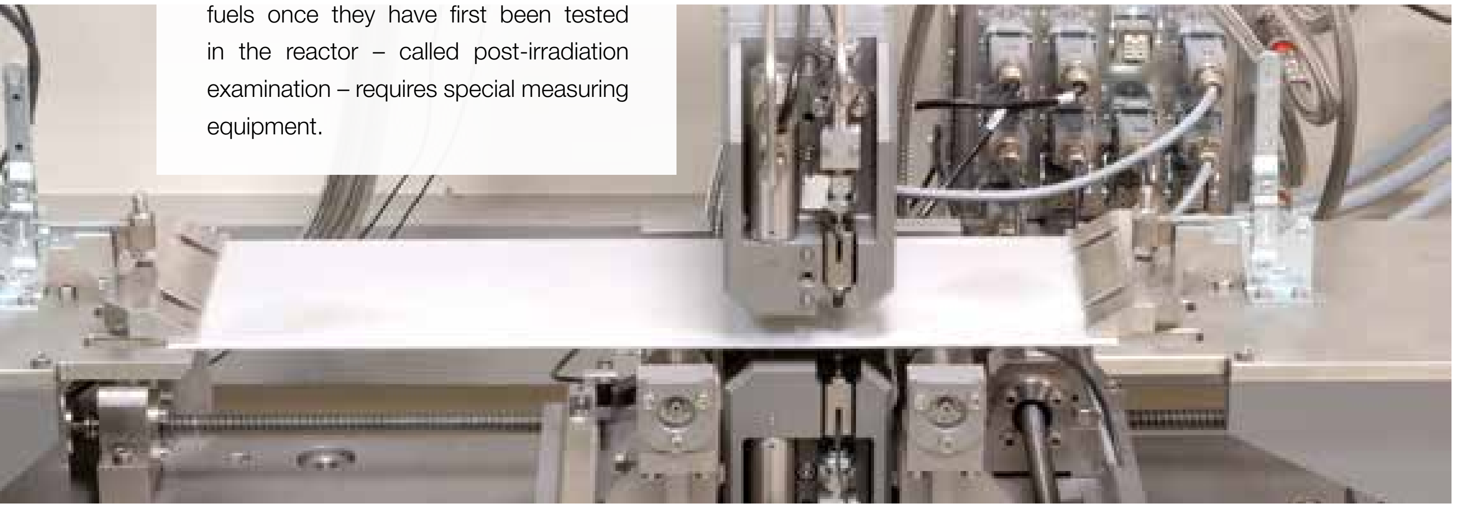
International interest in the BONAPARTE measurement bench

Post-irradiation examination of lower-enriched fuel plates

In the context of nuclear non-proliferation – preventing the potential dissemination of nuclear weapons – scientists worldwide are investigating the qualification of lower enriched fuel plates for research reactors. New and specific equipment is needed for the investigations to qualify these new fuel types.

To reduce the risk of proliferation further, test reactors such as BR2 should use fuel based on lower enriched uranium. In order to achieve this, researchers want to test these new fuel types under real irradiation conditions. This is called fuel qualification. To investigate these fuels once they have first been tested in the reactor – called post-irradiation examination – requires special measuring equipment.

One important parameter for establishing the proper behaviour of a fuel plate, typically used in a test reactor, is the degree of swelling of the plate. This is where the new BONAPARTE measurement bench developed by SCK•CEN plays an important part in fuel qualification programmes. It allows accurate full post-irradiation mapping of fuel plate swelling with a degree of precision of just a few micrometres.



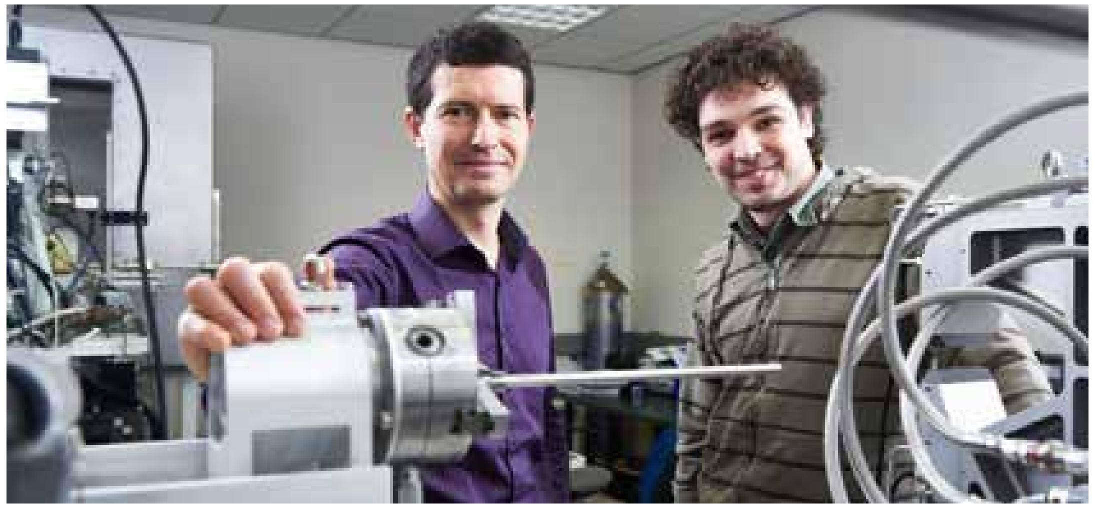
Not on sale anywhere

SCK•CEN needed such measuring equipment in a hot cell, but it is not commercially available anywhere in the world. In order to meet the needs of qualification programmes such as EVITA (U_3Si_2 fuel for the French Jules Horowitz reactor) and LEONIDAS (uranium/molybdenum-based fuel), SCK•CEN decided to develop its own measurement bench: BONAPARTE (Bench for Non-destructive Analyses on fuel Plate And Rod Type fuel Elements).

BONAPARTE had to be as modular as possible and be used for many different purposes: that was the ambitious plan. SCK•CEN wanted to deploy the measurement bench for various types and forms of irradiated fuel plates, even for conventional fuel rods. These fuel rods are employed in the BR2 irradiation programmes of test fuels for power reactors.

Armed with the necessary knowledge of hot cell equipment and a number of innovative ideas, SCK•CEN approached the engineering firm TEGEMA in Eindhoven to further develop and build the measurement bench. SCK•CEN staff took on the task of developing the software, electronic controls and data acquisition to make the measurement bench do exactly what is was built for.

> *“Idaho National Laboratory in the US commissioned an identical measuring device.”*



Accurate results

In mid-2011, the measurement bench was installed in a hot cell, and the first fuel plate was measured under a high radiation load. The researchers were rightly proud: the measurement results proved highly accurate and yielded a unique scientific insight that could not be achieved with earlier measurements. Since then, the BONAPARTE bench has successfully completed more than 20 measurement campaigns, including measurements of the SELENIUM fuel (Surface Engineering of Low ENriched Uranium Molybdenum) developed by SCK•CEN (see *Highlights 2012*).

The modular structure permits the BONAPARTE bench to be deployed for the measurement of both curved and flat fuel plates for test reactors. Specific modules for measuring fuel rods for power reactors have also been added to the bench.

3D mapping

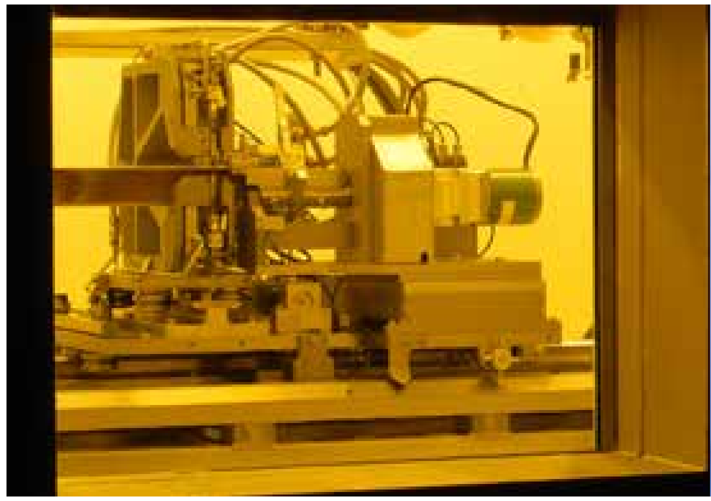
The BONAPARTE measurement bench is capable of measuring an entire fuel plate using three-dimensional axis control. Specially designed measuring probes that can withstand the high radiation field of such irradiated fuel plates scan the entire surface with highly accurate positioning. The thickness of the fuel plate and the thickness of the oxide layer are measured on both sides simultaneously with a precision of just a few micrometres and marked out in 3D mapping.

A unique dataset is obtained by combining the measurements with the known fuel consumption per mm^2 (calculated or measured). This allows computer models to be drawn up that can accurately predict the behaviour of the fuel swelling. This is invaluable for using the fuel under various conditions.

International interest

The BONAPARTE project has been watched with considerable international interest. There was much enthusiasm for this unique appliance, with tangible result. In early 2012, Idaho National Laboratory (INL) in the United States commissioned an identical measuring device from SCK•CEN under the BONA4INL project. Today, the BONA4INL measurement bench is fully qualified and ready for delivery. INL will use it for the fuel qualification programmes of the US Department of Energy within the RERTR programme (Reduced Enrichment for Research and Test Reactors).

Other laboratories, such as CEA (Commissariat à l'énergie atomique et aux énergies alternatives) in France and KAERI (Korean Atomic Energy Research Institute) in South Korea, have also shown an interest in the BONAPARTE measurement bench. SCK•CEN has gained much technological insight with the development, construction and validation of BONAPARTE. This will come in useful for the design of similar new measurement benches and other equipment for hot cell use in the future.



No one can play snooker that fast

SCK•CEN performs computer simulations of nuclear fuel behaviour

Gen-IV is the name of the next generation of nuclear reactors. Scientists are investigating which type of nuclear fuel is most suitable for Gen-IV. Safety and productivity are important, but so are nuclear non-proliferation and the life cycle of nuclear waste. How will these fuels behave in practice? SCK•CEN is performing computer simulations as part of the F-Bridge project.

During its time inside a reactor, the fuel is exposed to an extreme environment characterized by large temperature differences, chemical changes and radiation damage. In the long term, this inevitably leads to microstructural changes.

Targeted tests

For 50 years, nuclear fuel licences were awarded essentially on the basis of an empirical approach. Scientists made observations and over time they accumulated knowledge. This resulted in a large database about the fuels currently being used in nuclear reactors: uranium dioxide (UO_2) or mixed uranium and plutonium oxides (MOX). Given the high cost of creating such a database and the time needed (20 to 30 years), Gen-IV reactors will have to rely on more than just tests for their fuel qualification. A shift is needed towards a predictive approach, which involves gaining a better understanding of the primary phenomena down to the atomic level. This will make it possible to design new nuclear fuels that can be tested in targeted experiments. With this approach, the time and cost involved in developing new fuels can be reduced substantially.

Very short research

This targeted approach is not unique to the nuclear world. Many industrial processes nowadays make use of computer-aided design, long before production of the first prototype begins. One could say that computer simulation bridges the gap between theory (description of the main phenomena) and practice (design of a new product).

Nevertheless, this is not straightforward due to the complexities associated with nuclear fuels: their physical description involves different length and time scales, and covers different areas of physics. This interdependence is addressed by so-called ‘multi-scale modelling’, whereby the necessary macroscopic information is obtained from microscopic models.

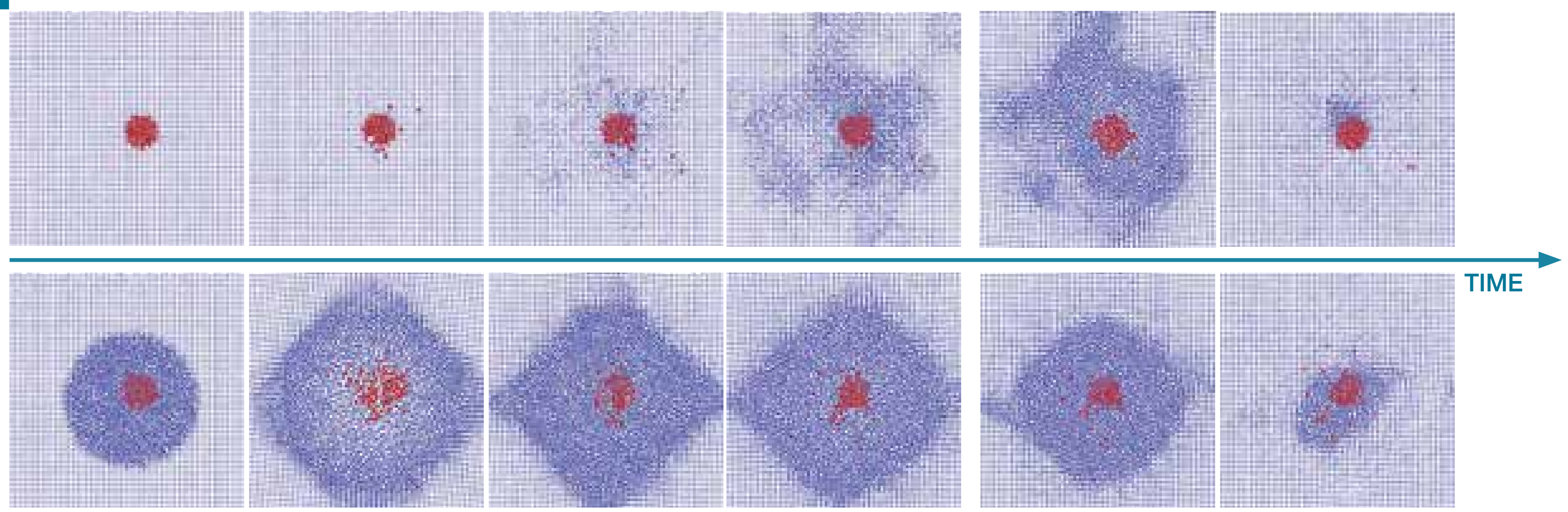
Researchers at SCK•CEN combine two worlds: determination of fuel efficiency and atomic-scale modelling. Determination of fuel efficiency involves examining the behaviour of the fuel elements as a whole over a number of years, whereas atomic modelling tracks the behaviour of a series of atoms over a short time scale. And that is very short; we are talking about thousands or millions of atoms over a period of less than a nanosecond, or one-billionth of a second.

Atomic-scale simulations

F-Bridge is about that very short research; it is an important project being funded under the seventh European framework programme. The objective of F-Bridge is to allow knowledge gained from fundamental science to be applied directly to the development of Gen-IV fuels. The ultimate goal is to set up an international exchange platform to have an integrated and coordinated approach to nuclear fuel research.

As part of the F-Bridge project, SCK•CEN collaborated with other institutes in Europe in a work package on multi-scale modelling. The main contribution of SCK•CEN is atomic-scale computer simulations. The techniques used are based on empirical force fields and describe atomic interactions using simple parameters and analytical formulas. Based on Newton’s theory, the evolution of a series of atoms and their interaction over a given time period can be predicted.

This is what the damage process looks like around a small gas bubble in the fissile material. *Above:* the damage caused by a fast neutron hitting an atom. *Below:* the damage following a collision with heavy fission fragments, causing more atoms to escape. In both cases, the system has gained the same amount of energy.



> “Researchers at SCK•CEN combine two worlds: determination of fuel efficiency and atomic-scale modelling.”

Flashy snooker

One interesting aspect is the process behind radiation damage. It is a bit like snooker. A computer can track the path of all the balls as soon as a player hits the white ball. Something similar happens here when investigating the damage caused by collisions with energetic particles. The main difference lies in the scale of the system: thousands or millions of atoms are involved in the process, and they are stacked three-dimensionally rather than in a horizontal plane. Moreover, the collisions are softer, as if you were to replace the snooker balls by rubber balls. The process also takes place very quickly, and it’s all over in just 10 to 100 picoseconds. That is one-hundredth to one-tenth of one-billionth of a second.

Despite its apparent simplicity, the bubble destruction process is an important step in the complex mechanism that enables these gaseous atoms to escape from the fuel. The very short time span makes it impossible to observe such a phenomenon in tests. It can only be done by computer simulation, which takes somewhat longer: one simulation involves calculations that take more than three months on a computer equipped with 16 processors.

Research on other nuclear fuels

In F-Bridge, research has so far focused only on uranium dioxide (UO_2), a fairly conventional fuel. The reason for this is that UO_2 is seen as the ideal candidate for testing the possibilities of the various techniques on a fuel whose behaviour is well known. In the long term, researchers want to investigate behaviours for which there is less experimental feedback available. The bubble destruction process is a good example. There is also research into phenomena that occur at grain boundaries as well as other nuclear fuels that may qualify for Gen-IV.

Further research will lead to an improvement of the modelling techniques. Arithmetical performance will improve once the researchers can use computers with new graphics cards – an application from the world of gaming that is of benefit to science. We will also see advanced acceleration methods and an improved description of atomic interaction. This approach will naturally serve as a guide for future experiments, but will not replace them.

04 Innovation for MYRRHA

Hamid Aït Abderrahim
MYRRHA Director

Today, 150 engineers, scientists, technicians and administrative assistants — SCK•CEN employees and external experts alike — are pushing along the MYRRHA project. Our colleagues come from no less than 27 countries. Furthermore, we are working together with a number of Belgian partners such as the von Karman Institute, Université catholique de Louvain, KU Leuven, Ghent University, Free University of Brussels, and more than 30 European institutions, thanks to research programmes supported by the European Commission.

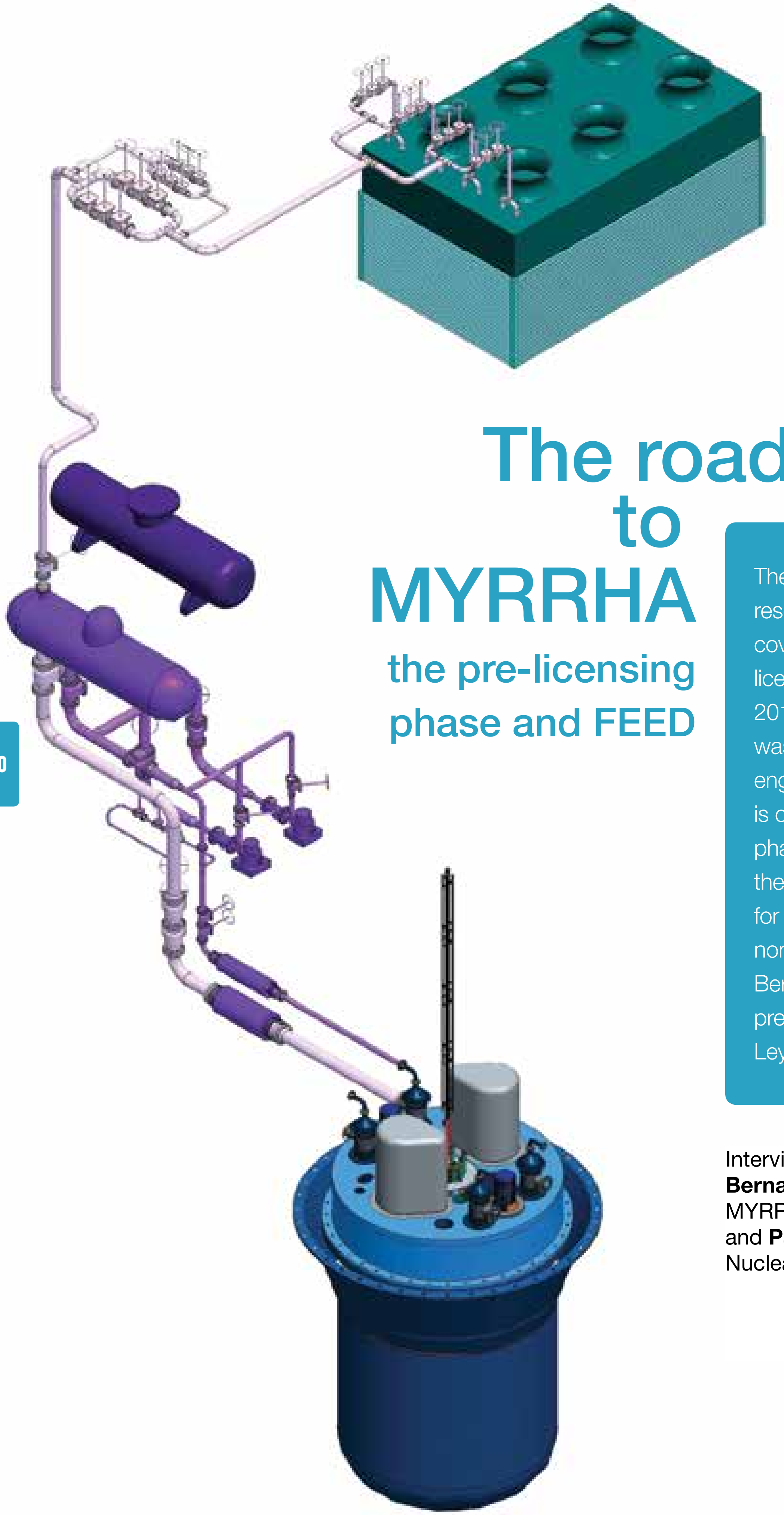
150 people work on MYRRHA

MYRRHA

In full, MYRRHA is short for 'Multi-purpose hYbrid Research Reactor for High-tech Applications'. This successor to the BR2 reactor represents a particularly innovative research infrastructure. MYRRHA operates with fast neutrons, and cooling takes place with liquid metal: a mixture of lead and bismuth. MYRRHA is the very first prototype worldwide of a nuclear reactor that is driven by a particle accelerator. We are referring to a subcritical reactor because the core does not contain enough fissile material to maintain the chain reaction spontaneously. It must be continuously fed by an external neutron source. This is the reason why the reactor is coupled to a particle accelerator. It is a technology that is safe and easy to control. When the accelerator is switched off, the chain reaction stops literally within a fraction of a second, and the reactor stops.

The fast neutrons ensure that the uranium fuel in the reactor is used more efficiently, and, as a result, there is less residual radioactive waste. Moreover, MYRRHA should demonstrate that it is technically feasible to process the most radiotoxic elements (neptunium, americium and curium) by transmutation. This fission of long-lived elements into products that are radiotoxic for a considerably shorter period of time ensures the further reduction of the quantity and the life span of the waste. This reduces the required storage time from hundreds of thousands of years to a few hundred years.

In addition to research into transmutation, SCK•CEN will deploy MYRRHA for a wide range of applications, including material testing for current and future reactors, nuclear fusion technology and the development of new nuclear fuels. In addition, there is also the production of medical radioisotopes, and the irradiation of silicon for electronics, which is used in wind turbines and hybrid vehicles, among other applications. SCK•CEN aims to put MYRRHA into use in 2025. The total cost has been estimated at € 960 million (2009).



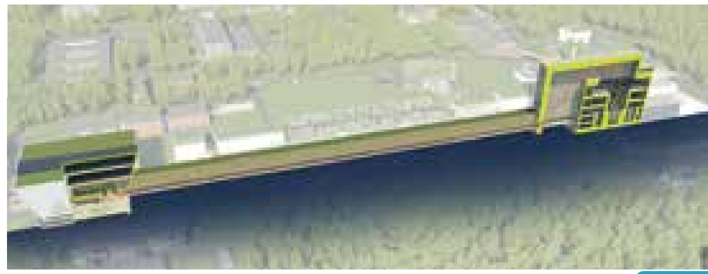
The road to MYRRHA

the pre-licensing phase and FEED

The study phase of the future research reactor MYRRHA covers three major areas: R&D, licensing and engineering. In 2013, substantial progress was made in the licensing and engineering processes: licensing is currently in the pre-licensing phase, while, for engineering, the FEED contract was signed for the construction of the non-nuclear parts of MYRRHA. Bernard Neerdael highlights the pre-licensing phase, while Paul Leysen discusses the FEED.

Interview with
Bernard Neerdael,
MYRRHA Management Team
and **Paul Leysen**, head of
Nuclear Systems Design

Bernard Neerdael
'We want to formulate a clear answer to all the focus points identified by the regulator.'



Why did the regulatory authority institute a pre-licensing phase for a project such as MYRRHA?

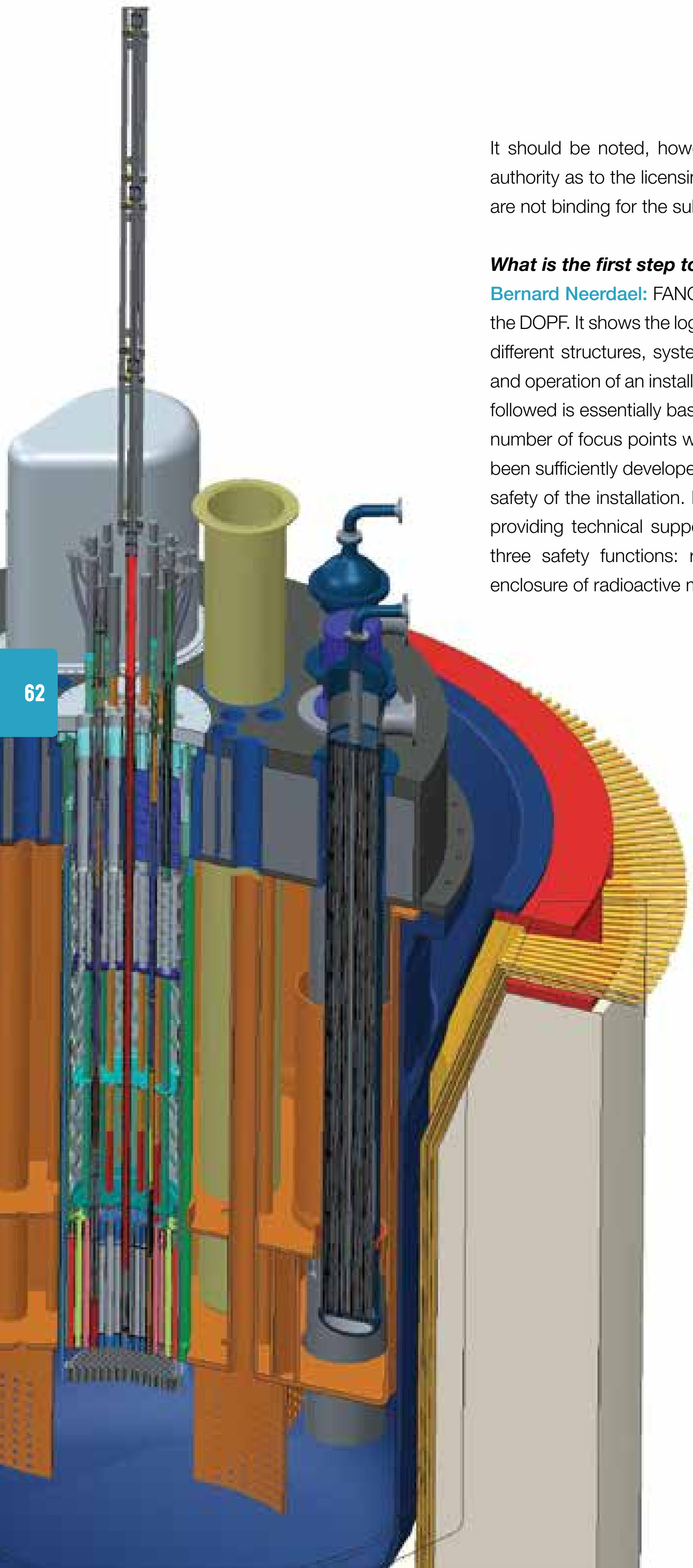
Bernard Neerdael: What SCK•CEN has in mind with MYRRHA is to build and operate a complex nuclear installation that uses innovative technologies. The regulatory authority must give its approval for every stage. In order to make this process run more smoothly in the long run, the Federal Agency for Nuclear Control (FANC) suggested the pre-licensing phase. This allows FANC to communicate its expectations from an early stage and during the development of the project. The pre-licensing phase was originally scheduled to run until the end of 2014, but has now been extended to the beginning of 2016 in view of how the design has evolved. Although this means a slightly longer pre-licensing phase, the licensing phase itself will be shorter as a result.

Is it easy to make a list of all the aspects required for the licence?

Bernard Neerdael: Every nuclear installation needs a set of permits from the regulatory authority: safety, environment, security, and of course planning permission. There is a lot involved. You have to comply with specific regulations, while the entire process must meet regional, national and international standards. Preparing the main elements of the licensing procedure involves a fair amount of work. Furthermore, the evolution of the design necessitates an iterative approach to the whole work process.

How far does research go in the pre-licensing phase?

Bernard Neerdael: The purpose of the pre-licensing phase is to provide detailed safety analyses as part of a 'Design Options & Provisions File' (DOPF). It involves a preliminary safety assessment of the installation as a whole. The file must correspond exactly to a set design of the installation that has been shown to comply with the regulatory authority's safety and security requirements.



It should be noted, however, that the conclusions of the regulatory authority as to the licensing of the installation in this preliminary phase are not binding for the subsequent licensing phase.

What is the first step towards the development of the DOPF?

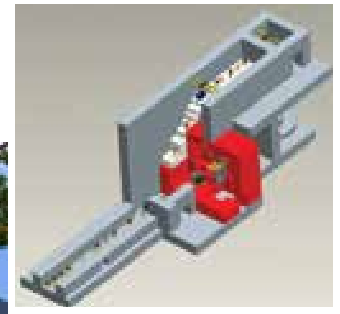
Bernard Neerdael: FANC has defined the structure and objectives of the DOPF. It shows the logical and necessary connections between the different structures, systems and components involved in the design and operation of an installation such as MYRRHA. The approach being followed is essentially based on the identification and assessment of a number of focus points which are either new to MYRRHA or have not been sufficiently developed yet, and which may have an impact on the safety of the installation. Bel V is also involved directly in this process providing technical support to FANC. The purpose is to ensure the three safety functions: reactivity control, guaranteed cooling, and enclosure of radioactive materials.

You have to focus on all of those aspects in the process?

Bernard Neerdael: Yes, we are expected to formulate a satisfactory answer to those focus points by the end of the pre-licensing phase. We communicate intensively with the regulatory authorities, so that eventually we can demonstrate with the DOPF that we meet the safety and security requirements. In that way, we create a solid basis and sufficient trust to move on to the subsequent licensing phase.

There is also talk of an environmental impact report ...

Bernard Neerdael: Yes, that's correct. Alongside the DOPF, an environmental impact report will analyse the expected human and environmental effects. This report will be assessed jointly by FANC and LNE (Environment, Nature, Energy). FANC is responsible at the federal level for assessing the radiological aspects, while LNE, a Flemish government department, will evaluate the non-radiological aspects.



We have to draw up several preparatory documents. Some of those documents will form the basis for public inquiries, so that everyone can have a say. The entire life cycle of MYRRHA will be covered, as we will investigate the environmental impact of the construction, operation and decommissioning phases of the installation. The final environmental impact report must be ready by the start of the licensing phase so that the planning application can be submitted to the local and provincial authorities. We are also working on a provisional decommissioning plan, intended for the National Institute for Radioactive Waste and Enriched Fissile Materials (ONDRAF/NIRAS).

What licensing aspects has the MYRRHA team been working on last year?

Bernard Neerdael: The team has mainly been occupied discussing and communicating the factual files for the focus points, 37 in total, and submitting the first reports. At the end of 2012, we submitted a first iteration of Volume 1 of the DOPF. Volume 1 describes the system components of the installation as a whole and the way they work. In 2013, we delivered Volume 2 to FANC. This volume focuses primarily on the safety approach and its implementation in the design process. We held regular meetings with the scientific board of FANC about all these documents and reports. Recently, the project memo on environmental aspects was completed and submitted for evaluation as a first step in the process leading up to the environmental impact report.

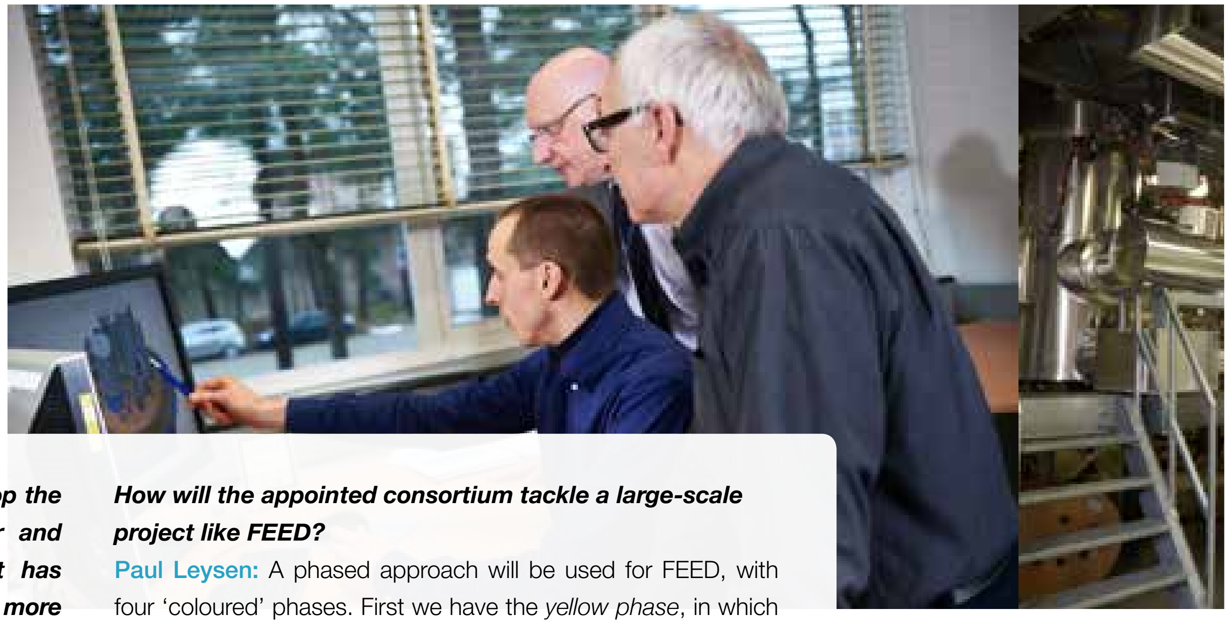
What is planned in 2014?

Bernard Neerdael: The remaining volumes of the DOPF: the choice and justification of design options and provisions, the integrated quality assurance system, security aspects and the control of nuclear materials (safeguards). In the course of 2014 we will start with an update of the file based on the revised design of the installation, recent research results, and the new input from the FEED contractor (Front End Engineering Design). The launch of the FEED project in 2013 was a major boost for many documents we are handling. The DOPF will eventually contain the answers to all the focus points and will thus become in 2015 the reference document containing all the necessary information and evidence required by the regulatory authority for the pre-licensing.

What are the objectives of FEED?

Paul Leysen: The consortium must work out the design project in such a way that we get an answer to three questions. *One:* what will the investment cost? The answer will be a budget estimate with a margin of around 25 percent. *Two:* can this innovative project be licensed from a nuclear point of view? FANC will have to answer that question. And *three:* how will the project continue? The answer to that question is a construction planning model in which the project is divided into twenty or so lots for detailed engineering and construction.

Paul Leysen
'FEED runs in four phases until mid-2016.'



Obviously SCK•CEN will develop the primary system – the reactor and related systems – because it has the know-how to do it. The more conventional aspects of the structure have been outsourced to an external consulting firm. Who was given the contract?

Paul Leysen: In 2011 we started the tendering process for this large contract. We followed the steps required by law, and in October 2013 we signed a contract with the selected consortium. This consortium is composed of Areva TA, Ansaldo Nucleare, and Empresarios Agrupados, with the Belgian company Grontmij as subcontractor of AREVA TA. Their job is to implement the design, what we call FEED, which stands for Front End Engineering Design. This will take approximately two and a half years, which is until mid-2016.

How will the appointed consortium tackle a large-scale project like FEED?

Paul Leysen: A phased approach will be used for FEED, with four 'coloured' phases. First we have the *yellow phase*, in which the primary nuclear process (reactor, cooling, essential buildings, enclosure and nuclear protection) is described in sufficient detail to provide answers to the focus points raised by FANC. This is followed by the *green phase*, in which the major cost items of the project are identified and budgeted. The third step is the *blue phase*: all the necessary elements are worked out in detail to enable FANC to draw up an entirely positive pre-licensing document. Finally, in the *red phase* everything is worked out in such a way that the cost estimate, construction planning, lot definition and specifications can be drawn up.

So FEED is now in the yellow phase?

Paul Leysen: Yes, that's right. The external consortium is busy collecting all the data that will form the basis for the design work. We will round off the yellow phase within a year, towards the end of 2014. This phase ends with a multidisciplinary overall engineering review, in which we bring together the design work of the various disciplines into one large whole that will form the basis for the green phase.

MEXICO loop provides essential technology for MYRRHA

SCK•CEN investigates the chemistry of lead-bismuth

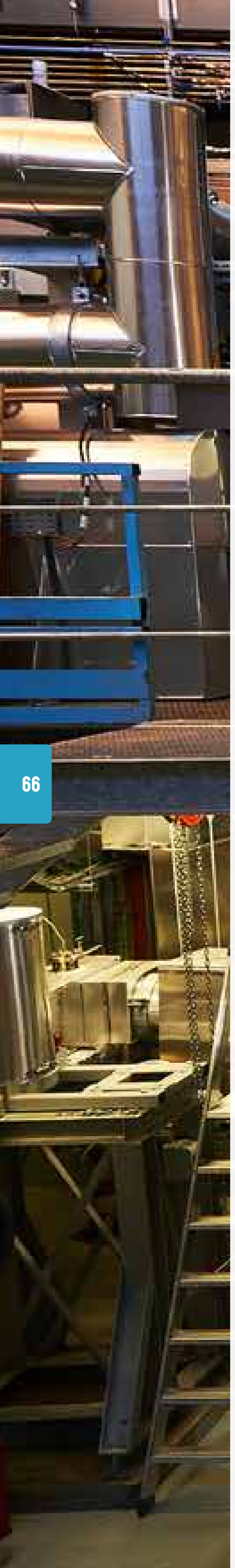
In MYRRHA, Lead-Bismuth Eutectic (LBE) alloy will act as the primary coolant. There are different experimental lead-bismuth loops in the world. Most have been designed to study steel corrosion in LBE or the thermohydraulics of LBE. MEXICO, a test loop developed by SCK•CEN, is unique in that it can be used to study the chemistry of lead-bismuth.

Studies by Russian and European research institutes have already shown that dissolved oxygen plays an important role in the LBE-induced process of steel corrosion. To keep this process under control, the oxygen level in LBE must be sufficiently high. A protective oxide coating will form on the steel structure. But too much oxygen is not good either, as the LBE coolant can begin to form oxides. Oxygen monitoring is therefore an essential technology to keep MYRRHA operating optimally throughout the entire planned lifecycle. It involves monitoring both the oxygen level and the quality of LBE, and minimizing contaminants by filtering.

Oxygen monitoring by MEXICO

SCK•CEN has developed the experimental MEXICO loop (Mass EXchanger In Continuous Operation) for the specific purpose of chemically controlling the LBE coolant technology. The first and foremost aim of MEXICO is to develop an oxygen monitoring system for MYRRHA. The dissolved oxygen in LBE will be consumed by structural steel oxidation processes in the primary system of MYRRHA. To keep the oxygen concentration at the required level, oxygen must be added to LBE in a controlled manner. This can be done by means of diluted oxygen gas, solid oxide, or a method using electrochemical oxygen pumps. All three methods are currently being investigated.

The first option chosen for MYRRHA was an oxygen monitoring system using a solid lead oxide mass exchanger. Engineers are studying the properties of lead oxide mass exchange in LBE in terms of kinetics, chemical stability and controllability.



> *MEXICO is a unique test loop to study the chemistry of lead-bismuth eutectic.*

Numerical modelling of the oxygen mass transfer

In order to predict the oxygen level in MYRRHA's primary system, SCK•CEN has developed a numerical model for oxygen mass transfer in LBE using a commercial CFD code (Computational Fluid Dynamics). The model will be validated on the basis of test results from the MEXICO loop. The validated model will then be ready to use for simulations of MYRRHA and for setting up a monitoring system that regulates the oxygen on the basis of the oxygen concentration. An additional purpose of MEXICO is to test the filtration system for purifying LBE.

Unique test loop

By coupling two heating zones and two heat exchangers, MEXICO has three temperature zones, instead of two as in most LBE test loops. This flexibility allows the researchers to efficiently study the coolant chemistry over a wide temperature range. A total of 23 oxygen sensors were set up in MEXICO at different positions from the highest to the lowest temperature zone. In this way, the variation in oxygen levels can be monitored throughout the loop. The sensors will produce data for validating the numerical model for oxygen mass transfer in LBE. The MEXICO loop also has two filtration systems to separate suspended solid contaminants and dissolved impurities.

SCK•CEN completed the final engineering design at the end of 2012. One year later, the construction work was completely finished. MEXICO is the result of a fruitful partnership between the *Conditioning and Chemistry Programme* unit and the *Design and Engineering Office*. Besides the design and construction work, some important technologies were developed and validated in 2013 for the operation of MEXICO, such as the manufacturing processes for high-quality lead oxide pellets and new sensors for measuring oxygen in a low temperature zone. A major experimental campaign will start in early 2014 that will yield valuable input for MYRRHA.

Milestone for FREYA

Royal Decree ratifies operating licence

On 6 November 2013, the Belgian Official Gazette finally published the Royal Decree ratifying the operating licence for the VENUS reactor. The first experiments with subcriticality measurements could begin at last. But first an intensive commissioning phase had to be completed.

Two years ago, the GUINEVERE project came up with a world first for the VENUS reactor. SCK•CEN managed to couple an accelerator in continuous mode (GENEPI-3C) to a fast lead core reactor (VENUS-F). That research project was part of the sixth framework programme of the European Commission. In this installation, research projects could now be carried out that are essential to the development of an accelerator driven system (ADS), which is the ultimate purpose of the MYRRHA project.

Accordingly, March 2011 marked the start of the FREYA research project: a European project under the seventh framework programme, coordinated by SCK•CEN. A total of 16 different institutes are taking part. One important partner is the French *Centre national de la recherche scientifique* (CNRS), which developed the GENEPI-3C accelerator for GUINEVERE. CNRS installed the accelerator and coupled it to the VENUS-F reactor for the first time in cooperation with SCK•CEN. Another important partner is the French *Commissariat à l'énergie atomique et aux énergies alternatives* (CEA), which supplied the uranium fuel for the reactor.

Validating codes and developing techniques

FREYA stands for 'Fast Reactor Experiments for hYbrid Applications' and has two main goals. *One:* developing a technique to measure the subcriticality of an ADS online. Unlike an ordinary reactor, an ADS is always slightly subcritical (see page 57). It is therefore necessary to know the subcriticality of the reactor at all times in order to be able to operate it safely. *Two:* validating calculation codes that will be used for MYRRHA. By comparing the results of experiments and calculations, the codes can be optimized and eventually validated.

Measuring subcriticality online

The FREYA project is divided into several technical work packages. The research tasks in the first package are focused entirely on the development and validation of a method for online subcriticality measurement. This happens in several subcritical reactor cores that are representative of an ADS. Several parameters are examined that are essential for subsequently obtaining an operating licence for an ADS. For example, the researchers test the applicability of the measuring technique in a deep subcritical reactor core, a situation that will occur when loading an ADS.

The second and third work packages are concerned with the validation of calculation codes that will be used for MYRRHA. Those studies are necessary for the design and licensing of MYRRHA. The researchers investigate which (critical and subcritical) reactor cores in VENUS-F can be loaded to be as representative as possible of MYRRHA. Once the cores are defined, they are loaded, and a new experimental campaign can begin. Those experiments, too, are simulated with the calculation codes. Comparison of the experimental and calculated results helps to optimize and validate the calculation methods for MYRRHA.

Lead-cooled fast reactor

Finally, a reactor core is to be loaded in VENUS-F to be as representative as possible of the lead-cooled fast reactor (LFR). Those studies are necessary for the design and licensing. *Ansaldo Nucleare*, one of the FREYA partners, is actually in charge of designing such an industrial LFR.

Commissioning phase

The commissioning phase encompasses all tests and relevant reporting that are necessary to obtain an operating licence for the installation from the regulatory authority. The first tests with the critical reactor core were intended for the core certificate procedure. The tests involved calibrating the safety rods and the control rods, and determining the radiation field around the reactor and the maximum neutron flux.

Once the critical core had been fully tested, the four central assemblies were unloaded to obtain a subcritical core

“On 6 November 2013, the ratification of the operating licence for the installation was finally published in the Belgian Official Gazette. The first experiments with subcriticality measurements could begin at last.”

and to install the accelerator. On 12 October 2011, a particle accelerator was successfully coupled to a fast lead reactor for the first time. This was followed by the necessary commissioning tests in this ADS configuration.

The research team reported the results extensively and sent the requisite documents to the regulatory authority to have the installation licensed. It was now a matter of waiting with bated breath. Meanwhile, staff of the *Nuclear Systems Operation* unit received training to run both the reactor and the accelerator. On 6 November 2013, the Belgian Official Gazette finally published the operating licence for VENUS-F. The first experiments with subcriticality measurements could begin at last.

Launch of the experimental programme

The aim is to develop and validate a technique to measure the subcriticality of an ADS. That will happen in the present subcritical core. As soon as the technique is available, specific experiments will be performed to investigate the robustness of the technique with a view to MYRRHA. There are specific positions in MYRRHA for the production of radioisotopes or for testing new materials and fuels under well-known experimental conditions that are independent of the reactor coolant. They will be simulated in the VENUS-F reactor to see whether they have an impact on subcriticality measurements. Then the core that is representative of MYRRHA will be loaded. This will mark the start of the next technical work package in the FREYA project.

1000 watts

maximum power of the VENUS installation

Peter Baeten

Advanced Nuclear Systems Institute Manager

1,000 watts is the maximum power of the VENUS installation in the GUINEVERE project. This can be compared with the lighting in an average house and is 100,000 times less than in MYRRHA. Nonetheless, this installation allows us to study all the physical properties of MYRRHA’s reactor core. The neutrons flying around don’t know if there are 10 or 1 million of them. VENUS is built like a Meccano set where all the parts can be easily changed, to make sure that the many experiments representative of MYRRHA can be carried out simply.

05

Safety as the top priority

219

studies and actions for safety

Fernand Vermeersch
Head of the Internal Service for Prevention and Protection at Work

The safe operation of nuclear facilities is extremely important, which is why every ten years, SCK•CEN organisational structure and facilities are subjected to an all-encompassing safety evaluation. Together with the initiatives arising from the stress tests, we currently have 219 safety studies and actions scheduled until 2018. Optimising safety is a permanent concern which not only requires a major effort from people as well as the necessary resources, but also a long-term vision.

Green light for the methodology file

Periodical safety review 2016 has begun

Every ten years, Class I nuclear facilities must undergo a thorough inspection. This means the regulatory authority and the operator perform a periodical and detailed safety review of the facilities. Such a review is a lengthy process and can only begin once the inspection method has been approved by the regulatory authority. The good news came in the summer of 2013 with the Federal Agency for Nuclear Control (FANC) giving the go-ahead for the safety review.

How reliable is a Class I nuclear facility? How will it behave over the next ten years? Do actions need to be taken to address the issue of ageing? What modifications are required to meet new standards? Are the structure and methodology of the organization still robust enough to operate the facility safely? Are the safety studies still adapted to the latest standards and techniques?

All these questions came up during the preparatory phase of the safety analysis of Class I facilities. This consists of 15 factors divided over six major areas: the safety situation of the facility, safety analyses, performance and experience management, management and organization, environmental impact, and radiation protection. Not a simple task, as the Belgian Nuclear Research Centre has nine Class 1 installations.

Methodology note

During a preparatory phase, the heads of the different installations first conferred with the *Health Physics* unit. This internal consultation formed the basis for determining the scope and methodology of the safety review. The methodology had to comply with the new guidelines of FANC. Once FANC had approved the methodology, SCK•CEN could go ahead with the actual safety analysis.

The approval came in mid-2013: the next three years will be devoted to the detailed review of the safety factors, as described in the methodology file.

FACILITIES TO BE REVIEWED

- BR1 reactor
- BR2 reactor
- BR3 reactor (in the process of being decommissioned)
- VENUS zero-power critical facility
- Hot cell laboratories
- Radiochemistry laboratories
- Laboratories for radiobiological and radioecological research
- Central Buffer Zone (interim storage of radioactive waste)
- Nuclear calibration building

"The review process culminates in the implementation phase, which starts in 2017."

Graded approach

The facilities at SCK•CEN are characterized by a great diversity in terms of activities, risks, operation, staff, complexity, and age. That is why a graded approach to safety analysis is best, as was also suggested by the International Atomic Energy Agency (IAEA). It is also more efficient to investigate certain safety factors at site level rather than at the level of the individual facilities. One example is the assessment of radiation protection.

Review and implementation

The detailed review of the various safety factors is set out in one report per factor and per facility. This is followed by an overall assessment report that includes suggestions for improvement and an implementation schedule. The review process culminates in the implementation phase, which starts in 2017: the proposed improvements are then put into practice under the supervision of FANC.

Certain improvements to the facilities or organization are actually the result of events outside SCK•CEN. Past incidents, such as the accident in Fukushima in Japan, led to safety reviews that are based on the feedback from those particular events.

Better accessible and more water supply

Radical measures to combat fires in woodlands efficiently

A forest fire has broken out on the SCK•CEN site. SCK•CEN's own fire brigade as well as the public fire brigade from Mol are called out. They use the jetties to pump water from the canal. The fire engines cross the bridges in the wood to reach the fire and put it out. Rest assured, this is just a fire drill. But this drill will take place in 2014.

A fire safety audit at SCK•CEN revealed that improvements were needed in the resources and facilities for combating fires that may threaten the site from outside. With an area of 335 hectares, the entire SCK•CEN site is ten times the size of the technical area. Furthermore, this includes a large area of woodland along the Bocholt-Hasselt canal. The auditors raised a very pertinent question: what will SCK•CEN do if a fire breaks out in the woods?

SCK•CEN is already making substantial efforts to prevent fire by removing dead wood, uprooting trees and keeping fire lanes clear. In dry summer weather, SCK•CEN's own fire brigade conducts awareness campaigns to urge staff not to start fires or to smoke in or near the woods. The brigade keeps an extra watchful eye at that time of year.

Points for improvement

Prevention is better than cure. However that is not enough, because the woodland around SCK•CEN is not so favourably situated: the prevailing wind could cause a fire to spread quickly to the site. After the audit, SCK•CEN began consulting with the local fire brigade, insurance companies and public authorities. The public fire brigade formulated an official position: the

> *"Fire engines can now drive up to the canal to set up pumps."*

preventive measures are satisfactory, but there are points for improvement as far as fire-fighting is concerned. A more extensive water supply is needed, and the fire engines must be able to reach every part of the woods.

Six water reservoirs, two bridges and two jetties

First of all, more water was needed. For this reason, water reservoirs have been built at six strategic spots in the woods. Fire-fighters can pump up to 1,000 litres per minute from such a reservoir.

Of course the fire brigade must be able to get to that water, and there must be access and escape routes. Previously this was not actually feasible, because the wood is bisected by the small Breiloop river. Two bridges have now been built to give fire-fighting teams clear access. Building those bridges in a conservation area was no straight-forward matter either. It required much study, because the bridges must be able to support a 15-ton fire engine.

A lot of water is needed to bring a large fire under control. The nearby canal provides SCK•CEN with a plentiful source of water, on the condition that the fire-fighters can get to it easily. This was not actually the case, as there is both a road and a line of trees running parallel to the canal. SCK•CEN has therefore built two jetties in line with the new bridges. Fire engines can now drive up to the canal where pumps can be set up to draw water.

Tour de force

The whole project was a tour de force. The *Central Technical Services* at SCK•CEN were faced with complex building methods. The bridges, for instance, are built on pile foundations. For the canal, heavy sheet piles were needed for the construction of the jetties.

The analyses conducted recently as part of the stress tests at SCK•CEN also revealed that one jetty will play a crucial role in supplying the technical area with water for extinguishing fire in the event of large-scale incidents. All constructions were completed in 2013 according to plan and are ready for use in fire drills and call-outs to forest fires by SCK•CEN's own fire brigade and the public fire brigades from Mol and Geel.

How to divide a site in two?

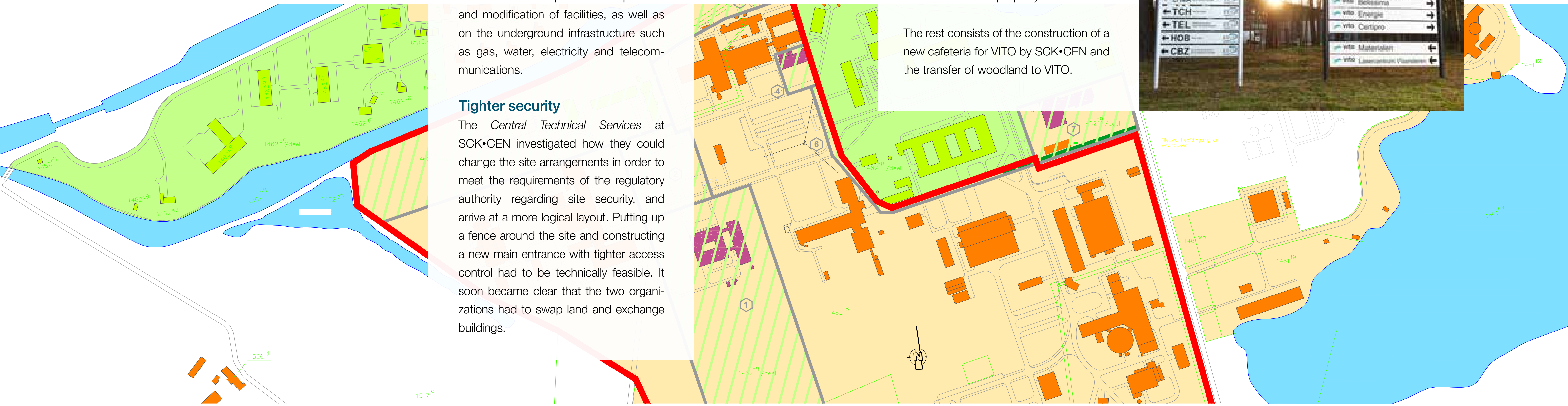
Towards a definitive separation of SCK•CEN and VITO

In 1991, the government decided to split up the nuclear and non-nuclear research activities at SCK•CEN. The non-nuclear activities were transferred to the Flemish Region, for which purpose VITO was set up. The land and buildings were divided as well: one-third Flemish and two-thirds federal. The result is a highly irregular pie shape.

The grounds of the Flemish Institute for Technological Research (VITO) and those of SCK•CEN intersect each other in an erratic fashion. The division was made artificially and there are no clearly demarcated halves. A logical division has several advantages: the two sites can be maintained and secured more efficiently. This is easier said than done, though. Rearranging and repartitioning the sites has an impact on the operation and modification of facilities, as well as on the underground infrastructure such as gas, water, electricity and telecommunications.

Tighter security

The *Central Technical Services* at SCK•CEN investigated how they could change the site arrangements in order to meet the requirements of the regulatory authority regarding site security, and arrive at a more logical layout. Putting up a fence around the site and constructing a new main entrance with tighter access control had to be technically feasible. It soon became clear that the two organizations had to swap land and exchange buildings.



“A logical separation makes the two sites easier to maintain and secure.”

Give and take

It was a matter of give and take. SCK•CEN receives 12.31 hectares of land from VITO and cedes 5.55 hectares to its neighbour. The energy building, block 3 of the chemistry building, the cafeteria and the documentation buildings are also transferred to SCK•CEN. Three other buildings remain with VITO, but the land becomes the property of SCK•CEN.

The rest consists of the construction of a new cafeteria for VITO by SCK•CEN and the transfer of woodland to VITO.

New main entrance

One remarkable operation is the construction of a new main entrance for SCK•CEN. Security on site is being tightened progressively, and this will also be noticeable at the main entrance, which will be located where the cafeteria and documentation centre are currently located. A new cafeteria will be built on this site as well, which upon completion will be transferred to VITO. The VITO site will remain open and accessible, which is logical. The grounds of SCK•CEN, on the other hand, will be completely fenced off, as they are today.

Separation by the end of 2016

The entire division was finalized legally at the end of 2013. A lot of work remains to be done by both VITO and SCK•CEN over the next few years, such as pulling down the present cafeteria and building a new one, along with the new main entrance. A fence will be erected as a physical boundary between the two sites. Naturally, the road infrastructure will also have to be adapted here and there. The new arrangement is expected to be ready by the end of 2016.

06 From research to business

In the space of six years, we have doubled our income. However, a contribution from the federal government which provides 50 percent of our annual operating budget is an absolute necessity in order to ensure the continuity and excellence of our research. To achieve our corporate goals, we can rely on the professionalism and enthusiasm of more than 700 employees and 70 PhD students.

Christian Legrain
Secretary-General

New technology for more effective cancer treatment

DoseVue, the first spin-off at SCK•CEN

Interview with
Emiliano D'Agostino,
DoseVue managing director

With 12.6 million new cases and 7.5 million deaths each year, cancer remains a major public health issue. Some 50 to 60% of patients undergo radiotherapy, sometimes in combination with surgery or drugs, as part of their treatment. DoseVue NV, the first spin-off at SCK•CEN, is developing technology to make high-dose radiotherapy more accurate and efficacious. Emiliano D'Agostino is one of the two founding partners of DoseVue, a promising new firm based in Hasselt.

How did DoseVue come about? Was there a demand from the medical sector?

Emiliano D'Agostino: Since 2008 I have been working for SCK•CEN on projects in which radiotherapy plays an important part. Those projects have always been in partnership with the medical sector, in which I have a background. Clinicians would put a pertinent question to us: 'We use computer models to determine the radiation dose. Naturally we verify many data at atomic level, but not on patients and certainly not on the tumour. Is there a method to calculate more accurately the dose being applied?' The latest technological developments make it possible to apply fairly high doses to a tumour. Yet it is crucial to make sure those doses are just right. We are now working on this refinement process.

What is the problem with high radiation doses?

Emiliano D'Agostino: The efficacy of radiotherapy can be improved by administering a high radiation dose to the tumour. At the same time, radiation of healthy tissue must be kept to a minimum. Did you know that today a cancer tumour can be irradiated with up to ten times the standard dose? That is why in routine clinical radiotherapy there is an urgent need for a non-invasive dosimetry system at the site of the tumour, particularly for high doses in one single treatment.

Acoustic behaviour

What exactly is the technology being developed by DoseVue?

Emiliano D'Agostino: The demand from the clinical community gave us the idea of using contrast agents to measure doses in a minimally invasive way. DoseVue's technology is totally new and consists of three major elements. *One:* the core elements in the dosimetry system are targeted and radiation-sensitive biocompatible microparticles with a diameter of a few micrometres. Their surface is covered with ligands (a type of molecule or ion) that bind to specific tumour receptors. *Two:* the properties of the microparticles change when exposed to ionizing radiation during radiation therapy. These changes in the physical properties are reflected in the acoustic behaviour of the microparticles. It is precisely this behaviour that can be measured by ultrasonic systems. *Three:* advanced signal processing algorithms compare the ultrasonic data before and after treatment. The dose information is encoded in the acoustic signals and is eventually converted into a three-dimensional dose distribution image. The system will give results on-line and in real-time.

Will you also develop your own devices for this?

Emiliano D'Agostino: The idea is to use existing ultrasonic scanners: we must keep the technology threshold as low as possible if we are to get our technology onto the market. A totally new device would hinder its introduction. It is also an advantage that our technology can run on existing devices: ultrasonic scanners are virtually omnipresent in the medical sector. DoseVue develops software that can read, analyse and convert the signals from the device into a dose image, or 'dose map'. Ideally we should be able to supply doctors with a laptop on which the software is already installed. All they have to do then is to connect the laptop to the ultrasonic scanner.

Eight years and twenty million

How far are you taking the development of the technology as a product?

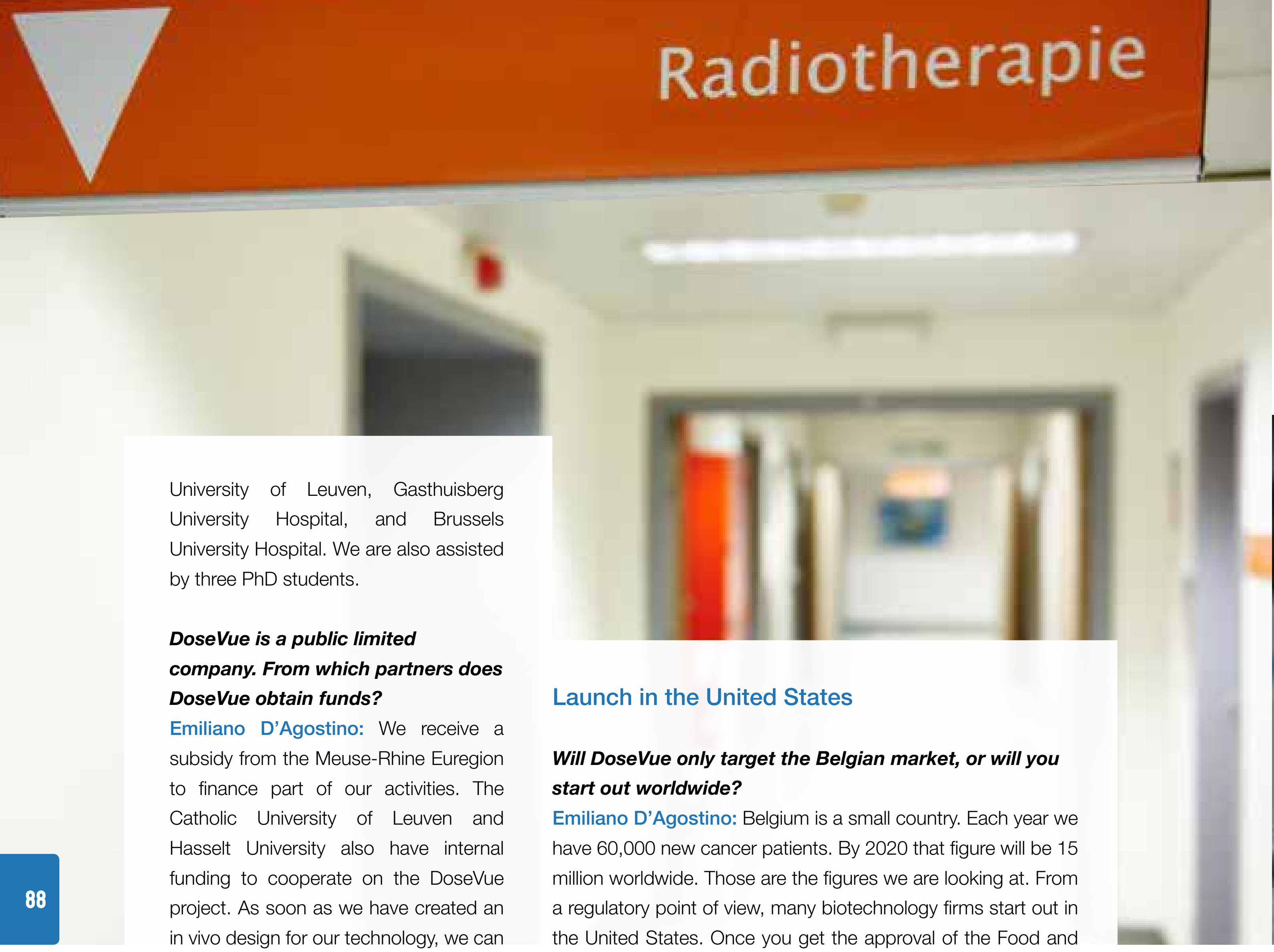
Emiliano D'Agostino: Our technology consists of two components: the software and the hardware. Through DoseVue and a number of partners we have raised funds that have allowed us to develop both software and hardware at the same time. Several software modules have already been finished. Naturally it is experimental software which is not yet finalized for use in the market. We are now primarily in the process of developing new materials and testing the robustness of the technology on an in vivo model.

"Ideally we should be able to supply doctors with a laptop on which the software is already installed. All they have to do then is to connect the laptop to the ultrasonic scanner."

The next step is industrialization of the product: we want to give the software an attractive graphical environment so that doctors can get results within just a few mouse clicks. I find it important to take the doctor's perspective into account: we do not develop anything without first sounding out whether he or she thinks it is necessary. The regulatory authorities regard the technology as a medicine, because the product is administered intravenously. That means a process of preclinical and clinical validation, involving a timeframe of eight years. We asked a regulatory expert to make a budget estimate of the total cost: 20 million euros. That's a lot of money, but still far less than for a conventional medicinal product.

What is planned right now?

Emiliano D'Agostino: In the next two years we will be finalizing the software to produce a first prototype and will then perform the in vivo tests. That may seem a long time, but for the moment it's just the two of us at DoseVue – my colleague Jeroen Hermans and myself: a very horizontal structure! We also work together with academic partners and hospitals: Hasselt University, Catholic



University of Leuven, Gasthuisberg University Hospital, and Brussels University Hospital. We are also assisted by three PhD students.

DoseVue is a public limited company. From which partners does DoseVue obtain funds?
Emiliano D'Agostino: We receive a subsidy from the Meuse-Rhine Euregion to finance part of our activities. The Catholic University of Leuven and Hasselt University also have internal funding to cooperate on the DoseVue project. As soon as we have created an in vivo design for our technology, we can approach other partners as well. This very important milestone will give us real opportunities to raise additional capital. We have already established the first contacts, and we are also looking out for other domains where our technology may be used. That is why we are in the process of developing certain new products to put on the market sooner, without ever losing our focus.

Launch in the United States

Will DoseVue only target the Belgian market, or will you start out worldwide?
Emiliano D'Agostino: Belgium is a small country. Each year we have 60,000 new cancer patients. By 2020 that figure will be 15 million worldwide. Those are the figures we are looking at. From a regulatory point of view, many biotechnology firms start out in the United States. Once you get the approval of the Food and Drug Administration, a large market opens up for you right away. It also makes the move to other countries easier.

Do you have any idea how DoseVue will develop as a company? It will soon be too much for two people to handle ...
Emiliano D'Agostino: Things are moving very quickly now. We have already hit our limit. Once we can clearly define our alternative applications, funds will become available to hire a third person. As soon as we move on from research and development to making prototypes, we will definitely need to recruit people with expertise in other areas: regulatory affairs, sales & marketing, etc. We don't have that expertise right now, but later on it will become just as important if we are to market our product successfully.

Will you be able to maintain the link with SCK•CEN?
Emiliano D'Agostino: SCK•CEN is currently a shareholder in DoseVue. It would be great if we could continue to tap into such a knowledge centre. We are SCK•CEN's first offspring, and together we stand stronger!

Towards a solid and diversified financial basis

Interview with
Christian Legrain,
Secretary-General

The Belgian Nuclear Research Centre will have to dig deep into its pockets in the next few years to pay for an ambitious investment programme. On top of the essential funding from the federal government, the centre will have to boost its own income. How will SCK•CEN meet this challenge? An interview with Secretary-General Christian Legrain.

What does the income situation at SCK•CEN look like in 2013? Is the federal government still the main sponsor?
Christian Legrain: It is true that, in the past, the Research Centre was very much dependent on the federal government, but that is less so nowadays. We have been at a level of 50% for a fair number of years now: one half consists of federal grants, while the other half comes from European programmes and clients in various fields. The federal government is definitely not expected to substantially raise its contribution in the near future, given the budgetary difficulties in Belgium and the European Union as a whole. So clearly we will have to become more self-sufficient.

What percentage do you have in mind?
Christian Legrain: The percentage will probably stay the same, but don't forget that our workforce has increased from 600 to 712 employees (680 FTEs), plus about 70 PhD students. This augments our cost structure. We remain 45 to 55% dependent on public funding, but the large-scale MYRRHA project has altered our situation drastically. SCK•CEN has hired more people, while investments are also higher in the current stage of the design. Naturally we still get support from the federal government for MYRRHA as was planned for the 2010-2014 period. The entire project (design and investment) is backed 40% by the federal government. The rest, we have to look for elsewhere. And that's a substantial amount of money. For that reason, we have been busy for several years setting up partnerships worldwide. We hope to give a definitive shape to that international consortium within the next 18 months.

Are the investments that large?

Christian Legrain: The total budget of SCK•CEN is 125 million euros per year. Our income consists of government funding, recurring revenues and other income, such as from projects and clients. We now need to find a good balance between recurring revenues and other income. As regards this 'other income', SCK•CEN is facing sharply rising investment costs for the first time in its history. Between 2003 and 2008, our annual investments increased from 3 to 5 million euros. In the last five years they have doubled to 10 million euros, and for the next three to six years we are facing an investment level of more than 20 million per year. That's another more than twofold increase!

What investments are in the pipeline for the coming years?

Christian Legrain: First of all, there is the MYRRHA project which I have already mentioned. Then there is the major overhaul of the BR2 reactor (see page 41). In order to guarantee that all the conditions for optimal operation are fulfilled, we need to invest 20 to 25 million euros within the next two years. To help pay for this, we will be approaching a third party within a few months. This marks a radical change from the financial model used in the past. That party will invest in the project and will be repaid after BR2 has been in operation for ten years.

Then there is the safety and security aspect: we need to invest in security because that is what society expects from a nuclear site. We hope that this investment, worth 21 million euros, will be covered by the public purse. Protection against terrorist attacks is the responsibility of the government. So far, however, I can only be certain of partial funding.

Here's another investment: after Fukushima, a number of stress tests for nuclear plants have been enforced at the European level. In Belgium, SCK•CEN must also prove that it meets those additional requirements. For this we have a plan ready costing 11 million euros. We do not know yet to what extent the federal government will finance this.

Finally, we also need to consider the situation of our residential quarter. We have a large social infrastructure there which we inherited from the past. Although it is not part of our core business to run that residential quarter, we still need to make certain investments to keep the infrastructure up to scratch. We are now looking for a partner to take over the operating concession. Any investment in the residential quarter will be repaid after 20 to 30 years.

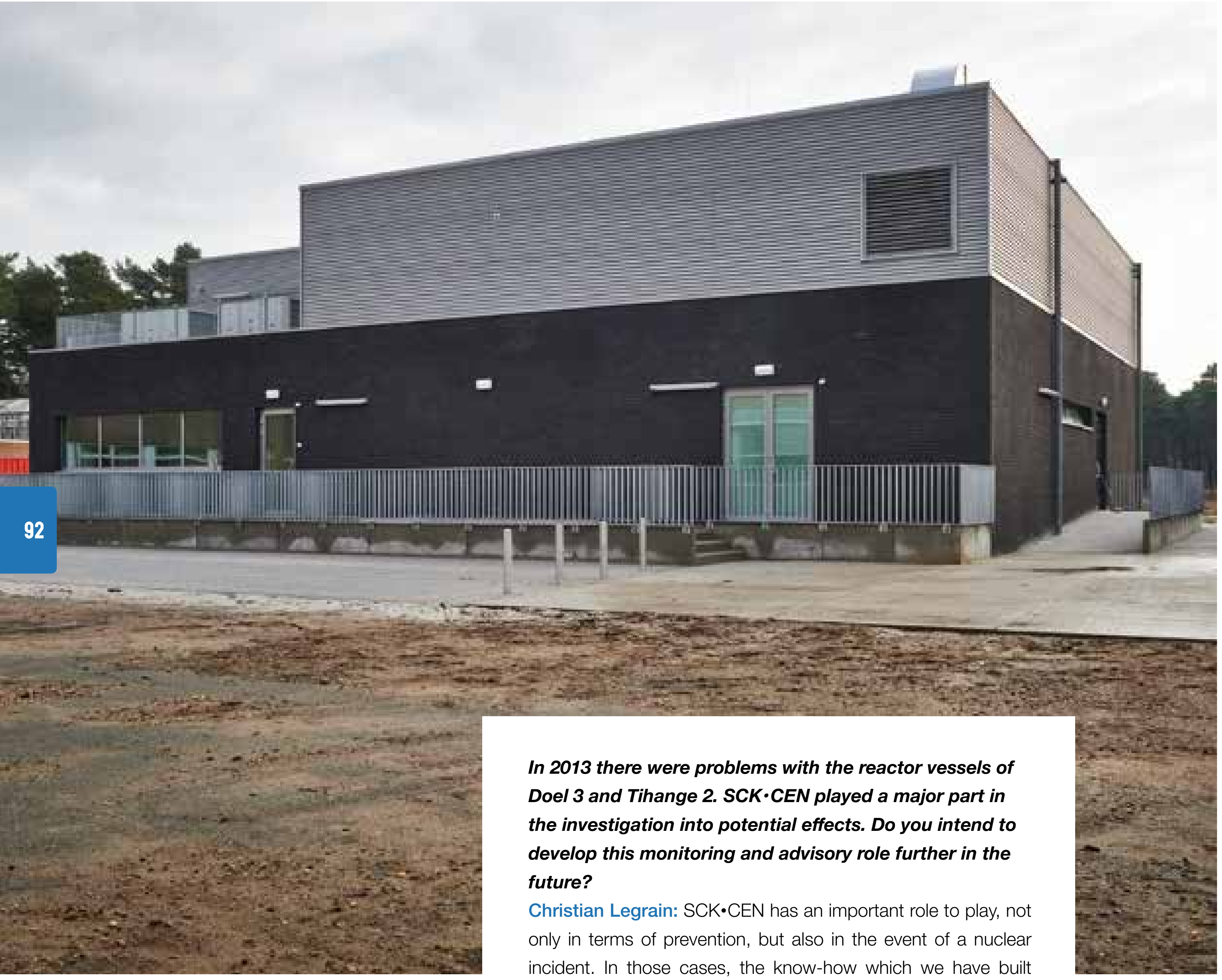
What other solutions do you have ready to handle all those investments?

Christian Legrain: We will work together more and more with partners. We will also have to set up a number of subsidiaries or companies. One test will undoubtedly be the funding for the overhaul of BR2. If all goes according to plan, we will transfer part of the commercial operations to a separate company that has yet to be set up. As a public utility foundation, SCK•CEN has the Belgian government as its sole shareholder. As a nuclear operator, however, we must remain the owner of the infrastructure.

> *"If we see an opportunity for developing a spin-off on a large scale, making use of our intellectual property, we will certainly do so."*

We have a number of large and small projects in the pipeline for which we are developing activities in other fields. For instance, we are in contact with a large radiopharmaceutical company. A partnership would open up a whole new world for us, because we would have to build new facilities. With such a project we hope to increase our recurring revenues. We may even look forward to the moment when a drug is put on the market that would earn us royalties on every product sold. That would be another first for us: recurring revenues from our R&D!

A telling example is DoseVue: for three years now, a few scientists have been developing a brand new technique in the field of cancer treatment (see page 83). They're doing this in Hasselt, not in Mol. Why in a different location? Because that activity is not part of the core business of SCK•CEN, but an outcome of our research. Once the project is ready for



production within eight years or so, with the support of third parties, we will be talking in terms of hundreds of millions. If we see an opportunity for developing a spin-off on a large scale, making use of our intellectual property, we will certainly do so.

In 2013 there were problems with the reactor vessels of Doel 3 and Tihange 2. SCK•CEN played a major part in the investigation into potential effects. Do you intend to develop this monitoring and advisory role further in the future?

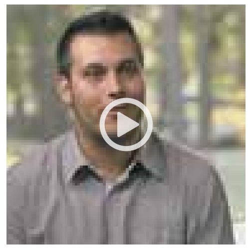
Christian Legrain: SCK•CEN has an important role to play, not only in terms of prevention, but also in the event of a nuclear incident. In those cases, the know-how which we have built up will be most valuable. This was demonstrated clearly during the investigation of the Doel 3 and Tihange 2 reactor vessels (see page 45). We are amongst the best in the world when it comes to offering a solution. The energy producers appreciate our knowledge and experience. That's why they decided to support SCK•CEN financially in order to preserve our expertise and infrastructure. This also provides the guarantee that this essential know-how will stay in Belgium.

'Just go for it all the way!'

Employees talk about their life and work in video testimonials

'No routine, a pleasant atmosphere, and you always learn something new. You are given ample opportunity for it. Just go for it all the way. Grasp it with both hands. And go. Do it!' This is Greet Verstrepen, a gamma ray spectrometry laboratory assistant, talking in a short video on the SCK•CEN website.

Engineers, ICT workers and technicians don't always find their way to the Nuclear Research Centre. Not because it is deeply hidden in the Campine woods, but because they don't know that SCK•CEN can be an attractive employer for them.



www.sckcen.be/jobs

Bridging the gap

Unknown is unloved. Candidates are often unaware of the opportunities that SCK•CEN offers, both professionally and in the private sphere. The HR department is trying to make the Centre better known amongst engineers, ICT workers and technicians by making SCK•CEN an attractive brand as an employer or, to use a technical term, 'employer branding'.

The department took its inspiration from testimonial videos on the websites of large companies. Often they are short, true-to-life testimonials by staff members. It seemed an excellent idea to enhance the recognition of working at SCK•CEN amongst prospective candidates.

Five testimonials

Five video testimonials are ready so far: two engineers, an ICT worker, a researcher, and a laboratory assistant. The camera follows them as they talk about their jobs. What is their working environment? What does a typical working day look like? What do they appreciate in the organization? Those spontaneous testimonials show that SCK•CEN has a lot to offer: a wide diversity of colleagues, scientific challenges, and a good work-life balance.

More applications

SCK•CEN uses the videos on its own website, at job fairs and on sites where job vacancies are advertised. Anyone whose interest is kindled by one of those videos can apply by sending a letter to one central e-mail address on the job vacancy pages of the website: jobs@sckcen.be.

Requesting a scientific article with one mouse click

Brand-new library software puts knowledge within easy reach

"The conversion of data from Biblios to Brocade was a formidable task which will save us a lot of work in the future."

The SCK•CEN catalogue used to be managed with *Biblios*, a digital library system dating from the last century. It was coming apart at the seams and was urgently in need of replacement. So SCK•CEN went in search of a new software system to manage the current catalogue more easily. After a market study, the contract went to the firm Cipal in Geel; they implemented the library software *Brocade*, which was developed at Antwerp University.

The first challenge in the partnership with Cipal was to organize the data contained in Biblios. The earlier data was highly disorganized, due in part to human error as it had always been entered manually. It was therefore essential to convert everything properly for the new system. This conversion proved to be a formidable task, but will save SCK•CEN a lot of work in the future.

Subscription management

Subscriptions to journals and other publications can be managed perfectly in Brocade. This will reduce the workload considerably as many actions are automatic. For instance, the system generates a daily list of issues of subscriptions to be received, which allows quick distribution. The full collection and all subscriptions are visible to everyone in Brocade. When someone uses the search engine, he/she instantly gets to see all search options and search results of the complete library. More structure gives a better overview.

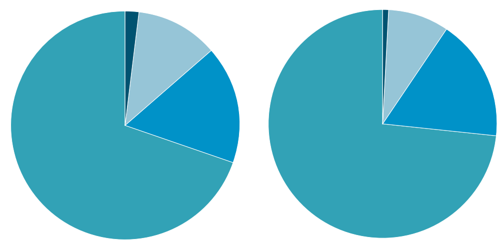
New front office

A new digital front office has been created to bring all data visually closer to the end user. The catalogue of books and journals can now be searched in an instant. Articles and books that are not in the collection of SCK•CEN can also be requested via the front office. There are also a few links to allow searches of other databases, such as 'Web of Knowledge' (database for scientific publications) or NBN (specifically for standards, with a distinct collection of standards already purchased by SCK•CEN). Finally, all scientific publications by SCK•CEN staff, the so-called 'Scientific Output', can be consulted, and researchers can add their new publications.

Yet more search options

Now that the implementation of this new software and the conversion of the existing data have been completed, SCK•CEN wants to offer yet more search options. One of those is the 'linksource' module. This will enable end users to search different databases and to see straightaway whether the Centre's library has a subscription to a particular journal. If SCK•CEN has a digital subscription, the end user can download the article immediately. If not, an online form to request the article is available. This is done with one mouse click, which – like the whole library system – is a tremendous step forward.

Scientific output

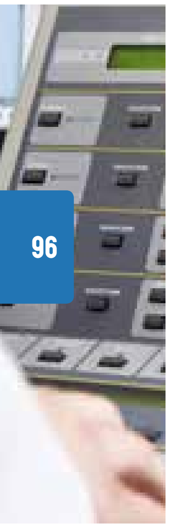


	2012	2013
Books	12	7
In-proceedings papers	67	56
Journal articles	98	113
Presentations	403	483

Sharing and dissemination of scientific knowledge is one of the core tasks of SCK•CEN. For this reason, researchers present the work they are doing at numerous international conferences. In addition, many publications appear in magazines and other media.

2013
An exceptional year

2013 was a special year in several respects. Despite certain internal challenges that called for the necessary budgets, SCK•CEN still managed to realize an overall turnover of 79.3 MEUR (own income) which is 31.3 MEUR more than in 2012. The increase is primarily due to an additional cycle in the BR2 reactor to ensure the supply of medical radioisotopes, new material tests and analyses for the Doel 3 and Tihange 2 reactors, studies into radiopharmaceutical products and additional scientific research assignments.



Social balance sheet for 2013
Number of employees as on 31 december 2013

	Fulltime	Parttime
Under a Contract of Employment for an indefinite duration	563	77
Males	505	51
Females	127	29
Employees joining service	71	0
Employees leaving service	60	5
Average number of employees	624	82
Total	632	80

Comparative balance sheets
(in kEUR)

Assets	31/12/13	31/12/12
Intangible fixed assets	4,910	3,499
Tangible fixed assets	33,303	29,614
Financial fixed assets	6,197	6,182
Receivables for more than one year	216	0
Stocks, work in progress	29,190	19,842
Amounts receivable within one year	37,786	33,133
Current investments	21,865	31,039
Cash at bank and in hand	79,392	48,546
Deferred charges and accrued income	3,243	3,191
Total	216,102	175,046

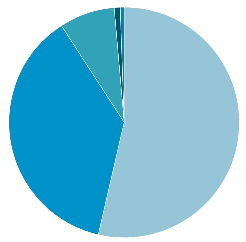
Liabilities	31/12/13	31/12/12
Equity	49,818	45,094
Provisions for liabilities and charges	113,563	93,240
Amounts payable after more than one year	0	0
Financial debt	0	0
Trade debt	22,246	8,664
Advances received on contracts in progress	19,996	18,896
Taxes, remuneration and social security	7,674	7,145
Other debt	9	28
Accrued charges and deferred income	2,796	1,979
Total	216,102	175,046

Together with the grants and subsidies from the federal government, the income (revenues) totalled 147.29 MEUR. This amount also includes the financial and other income, such as the reduction in payroll withholding tax for scientists.

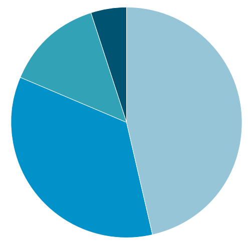
The total costs of SCK•CEN amounted to 147.96 MEUR in 2013, or an increase by 29.34 MEUR. SCK•CEN recorded a near-breakeven result of -674 kEUR, compared with a loss of 4.6 MEUR in 2012.

The *Purchases and Services* package, accounting for 35% of total costs, rose by 17% to 51.58 MEUR, primarily due to higher waste costs. The other *Purchases and Services* remained on the same level as in 2012.

Income 2013
(in kEUR)



Charges 2013
(in kEUR)



Income	kEUR	Charges	kEUR
Turnover	79,298	Personnel costs	68,912
Subsidies from government, grants	54,570	Purchases, Services	51,584
Other	11,402	Provisions	20,323
Financial income	1,492	Depreciation	7,141
Extraordinary income	524	**Total**	**147,960**
Total	**147,286**	Transfer to Allocated Funds	0
		Net result	**-674**

In 2013, personnel costs accounted for 47% of the total costs (compared with 55.5% in 2012). The workforce increased further to 712 at the end of 2013. Personnel costs rose by 3.1 MEUR to 68.9 MEUR.

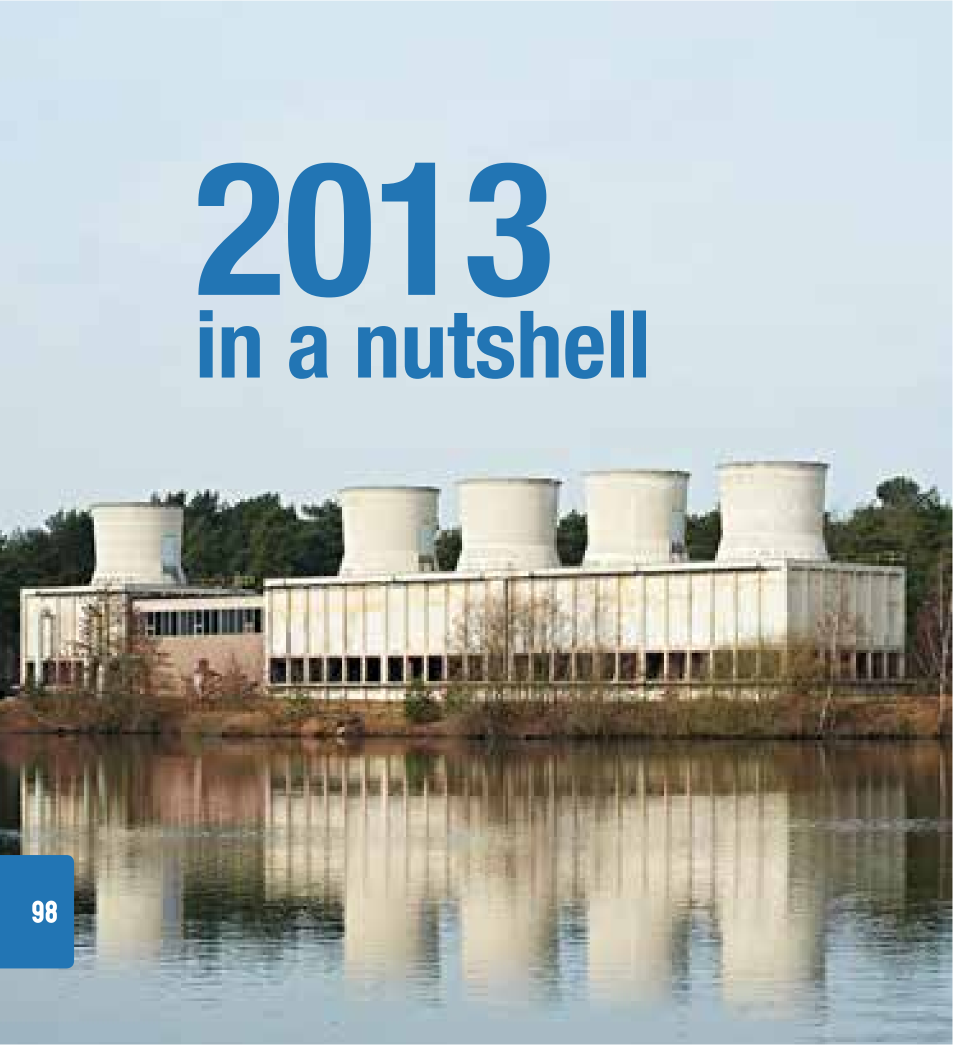
Every year, SCK•CEN concludes a number of four-year contracts for PhD research with various Belgian universities. This currently involves some 65 PhDs for which the current commitments amount to 6.03 MEUR for the next four years. Most of this amount is financed by SCK•CEN, with the rest being provided by external sources of funding such as industry, FWO (Fonds Wetenschappelijk Onderzoek - Scientific Research Fund), and European framework programmes.

SCK•CEN constituted provisions in 2013 to the amount of 22.8 MEUR for anticipated expenditure in the coming years. 2.5 MEUR of the current provisions was spent. The new provisions essentially concern anticipated expenditure for site security, price increases for waste processing, the dismantling of the sodium plant pending a positive decision by Royal Decree, and for major maintenance works.

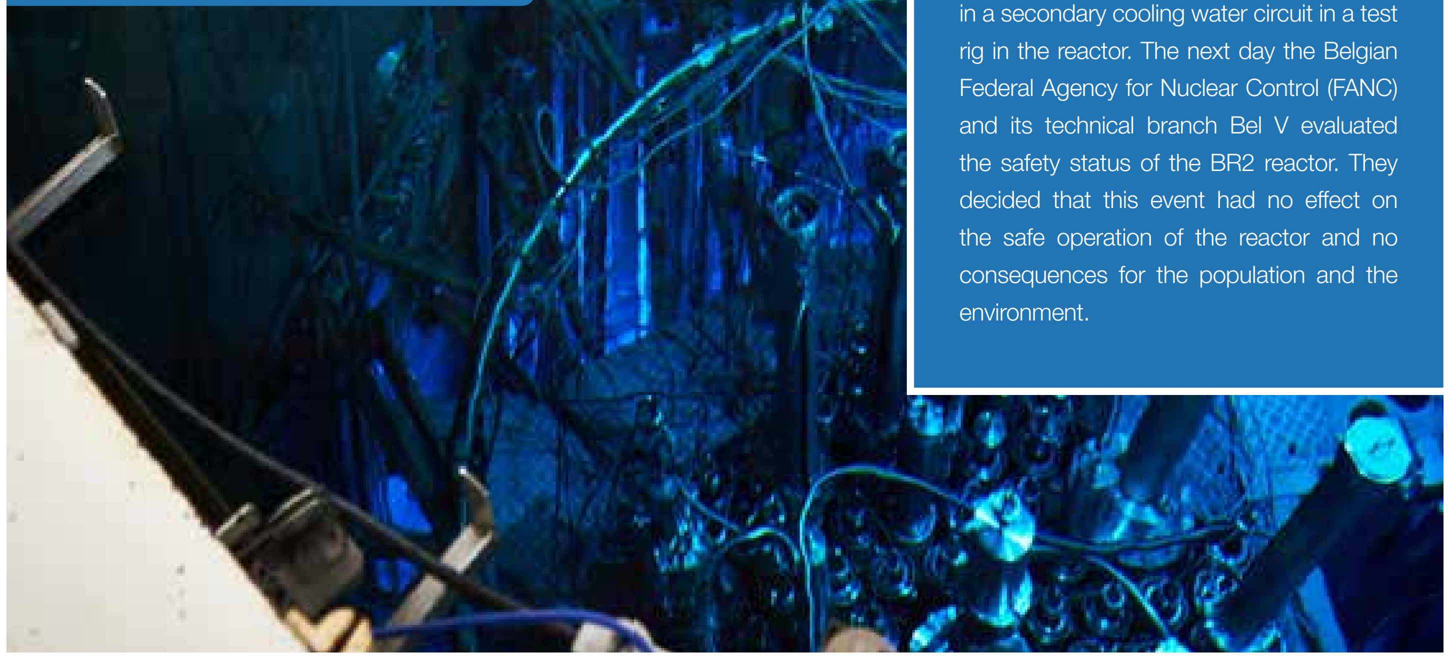
The exceptionally high own income in 2013 resulted in an increase in financial resources by 21.7 MEUR. At the end of 2013, the financial resources and provisions represented 47% and 52.5% respectively of the balance sheet total. The operating capital decreased by 1.9 MEUR this year, which also contributed to an improved cash position. The equity of 49.8 MEUR amounts to 23% of the balance sheet total.

In 2013, SCK•CEN invested a total of 12.2 MEUR, primarily in the renovation of buildings, infrastructure works and MYRRHA. There were also replacement investments in the installations and in safety and security, such as a new fire engine.

Over the next few years, SCK•CEN expects major investments in the renewal of the BR2 reactor, the realization of the MYRRHA project and the ongoing renovation of buildings. Further investments will also be made in the physical security of the site in the near future. This is the result of the actions from the stress test and the tightened safety standards for nuclear installations.



2013
in a nutshell



APRIL

SCK•CEN temporarily meets up to 50% of world demand for medical radioisotopes with extra production cycle

The BR2 reactor at the Belgian Nuclear Research Centre runs an additional cycle for the production of radioisotopes for nuclear medicine. This guarantees supplies to Belgian and foreign hospitals. Each year, SCK•CEN supplies 25% of the world's demand for molybdenum-99. From this, hospitals obtain technetium-99m. This is used in 80% of all medical examinations involving radioisotopes. At peak times, the BR2 reactor can supply 65% of the weekly demand.

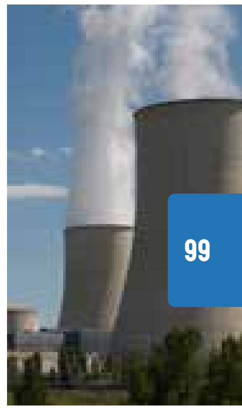
AUGUST

The BR2 reactor can be restarted after green light of FANC and Bel V

On 13 August, the BR2 reactor was taken off-line as a precaution and put into safe mode. This was the consequence of a leak in a secondary cooling water circuit in a test rig in the reactor. The next day the Belgian Federal Agency for Nuclear Control (FANC) and its technical branch Bel V evaluated the safety status of the BR2 reactor. They decided that this event had no effect on the safe operation of the reactor and no consequences for the population and the environment.

SCK•CEN signs memorandum of understanding with Fukushima University

On 29 August, SCK•CEN and Fukushima University signed a close and long-term cooperation agreement, in the presence of the Japanese ambassador Mitsuo Sakaba. The focus is on research into the transfer of radioactive substances from the soil to plants, and remediation techniques to reduce the absorption of these substances by plants.



OCTOBER

GDF SUEZ invests 12.5 million euros in SCK•CEN research projects

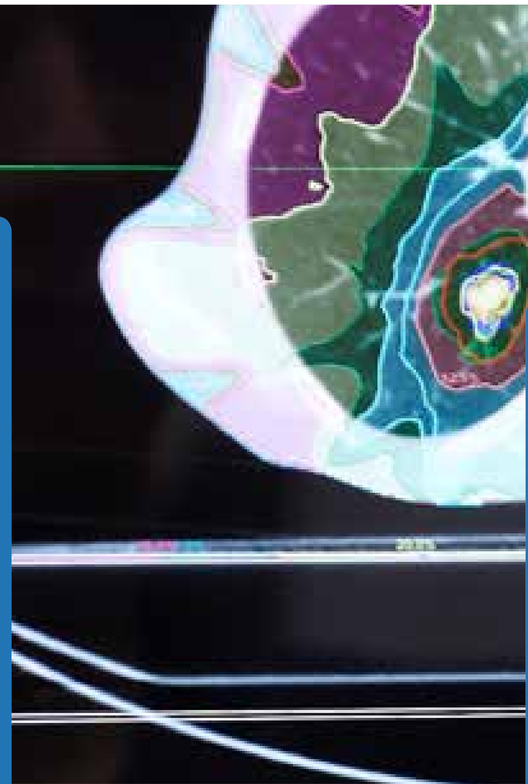
GDF SUEZ and SCK•CEN have signed an R&D cooperation agreement. This signals the continuation of a cooperation that began back in 2007 with a joint effort by GDF SUEZ and SCK•CEN to maintain the international excellence of Belgian research. This new agreement, with a potential value of 12.5 million euros, will run for five years. During this period, it will guarantee work for an average of 15 researchers.

Rad4Med.be puts Belgian expertise in the nuclear medicine into the limelight

Rad4Med.be was founded by SCK•CEN, IRE, IBA and the Health Competitiveness Cluster of Wallonia (BioWin). It is the first Belgian network for all medical applications of radiation. Rad4Med.be currently has more than 40 partners who will promote Belgium's unique expertise in this field both in Belgium and abroad. The mission: to contribute to the industry's growth and create additional employment, but also to contribute to the training of experts. A presentation during the royal mission to South-Africa was the jewel in the crown of the Rad4Med.be launch.

'Our presentation about Rad4med.be was very well received', said an enthusiastic Eric van Walle, SCK•CEN Director-General. 'We are giving insufficient attention to the pioneering role Belgium is playing in the field of nuclear medicine, and how crucial this sector is for responding to the many challenges we still face in the area of public health. Our country should therefore continue to invest in research and innovation in order to maintain its position as a world leader in nuclear medicine.'

Rad4Med.be
THE BELGIAN NETWORK FOR RADIATION APPLICATIONS IN HEALTHCARE



Minister-President of the German-speaking Community visits SCK•CEN

Karl-Heinz Lambertz, the Minister-President of the Belgian German-speaking Community paid a working visit to SCK•CEN. 'I am really impressed by the high degree of professionalism. We must improve and strengthen the know-how present in Belgium. In the future, there will be many more applications of this technology, which will be of relevance both within as well as outside the field of energy. Thanks to the Belgian Nuclear Research Centre, we have high-performance research facilities to do this', says Minister-President Lambertz.

CERN and SCK•CEN join forces to develop particle accelerators

The Belgian Nuclear Research Centre and the European Organization for Nuclear Research (CERN) are going to work together intensively to develop high-intensity particle accelerators. CERN in Geneva is a world authority in the field of accelerators, and SCK•CEN has also been able to build up a great deal of expertise, together with numerous Belgian and European partners, in the area of accelerator technology, in particular on improving the reliability of the proton bundle. The two institutions will exchange researchers under the terms of this cooperation agreement and SCK•CEN will be able to make use of CERN's facilities.

SCK•CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

2013 highlights

SCK•CEN
Belgian Nuclear Research Centre
SCK•CEN is a foundation of public utility, with a legal status according to private law, that operates under the tutorship of the Belgian State Secretary in charge of Energy.

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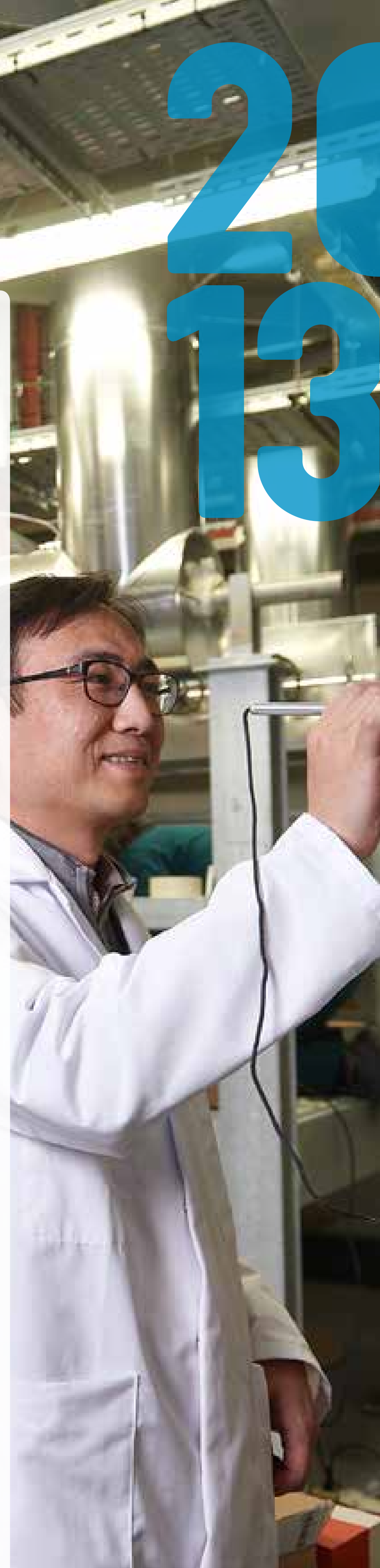

SCK•CEN

Belgian Nuclear Research Centre

60 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 700 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

Want to know more about SCK•CEN?

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