Australian Nuclear Science and Technology Organisation

future vision>

Australian Government

Nuclear-based science benefiting all Australians

Executive Director Introduction

The Australian Nuclear Science and Technology Organisation (ANSTO) is the centre of Australia's nuclear science capabilities and expertise. We are one of the nation's most unique and valued scientific assets.

ANSTO produces radiopharmaceuticals to help in the diagnosis and treatment of a range of serious illnesses. We also help solve a wide range of industrial and environmental problems. Our ability to deliver these solutions is made easier by our international reputation for undertaking outstanding, innovative scientific research. A further significant strategic activity ANSTO undertakes is providing impartial advice to government on a range of important long-term issues, including climate change, power generation and counter-terrorism.

In the international arena, we contribute to regional and global initiatives that will make the world a safer place in which to live. For example, we advise countries in the Asia-Pacific on effectively managing radioactive materials for medical and industrial uses. We are also helping other countries find better ways to store their radioactive wastes without compromising the environment or human safety.

ANSTO is on the edge of a new era, one in which our nation's prosperity and the well-being of its citizens are linked to our ability to compete technologically on the world stage. By funding the construction of a new research reactor – OPAL – the Australian federal government has taken an important step towards securing Australia's future in an age of increasingly sophisticated industrial and medical technologies.

The OPAL research reactor will make it possible for us to deliver an extensive range of radioisotope products and industrial services to Australian and overseas customers. Our products and services will therefore become even more significant in improving the health of Australians through better medical diagnostic tools and treatments. OPAL will also be a boon to the national economy, extending the unique analytical capabilities businesses can tap into.

OPAL will enhance our research capabilities, increase the range of world-class research programs we undertake and attract the best researchers from around Australia and throughout the world to collaborate with us. One exciting area we anticipate becoming a world leader in is neutron scattering science. This discipline is set to provide insight into some essential biological processes of the human body, in addition to its established contributions to materials and engineering science.

Our research programs will continue to reflect Australia's national priorities, just as our staff will continue to excel scientifically as well as demonstrate the highest standards of professionalism and integrity in all aspects of their work.

Ian Smith
Executive Director
February 2006

vision & mission

Vision

To be recognised as an international centre of excellence in nuclear science and technology for the benefit of Australia

Mission

To support the development and implementation of government policies and initiatives in nuclear and related areas, domestically and internationally

To operate nuclear science and technology based facilities, for the benefit of industry and the Australian and international research community

To undertake research that will advance the application of nuclear science and technology

To apply nuclear science techniques and expertise to address Australia's environmental challenges and increase the competitiveness of Australian industry

To manufacture and advance the use of radiopharmaceuticals which will improve the health of Australians

Accessing ANSTO

To ensure that Australian industry can really benefit from ANSTO's specialised technology, research and services, we have set up a contact 'portal' called Access ANSTO.

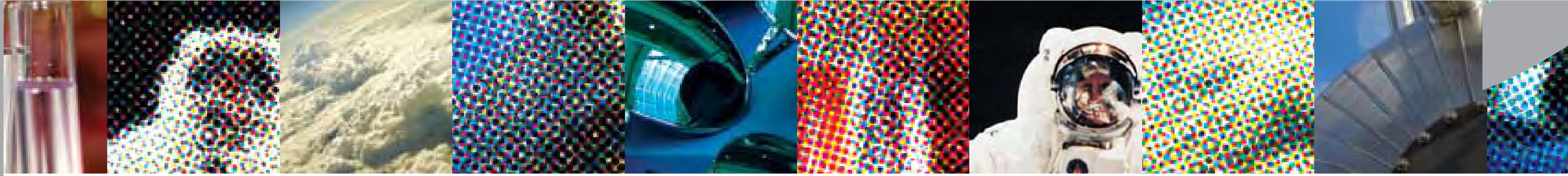
The head of Access ANSTO, Warren Bradey, says one of their jobs is to put industry groups and commercial companies in touch with ANSTO research teams who can help them.

Companies are also encouraged to work with Access ANSTO staff to develop and commercialise new ideas and innovations. This gives the companies access to high-tech capabilities, infrastructure and unique equipment that they might not otherwise be able to afford. It also ensures that ANSTO staff understand industry needs.

Access ANSTO also helps connect industry researchers with the most appropriate parts of ANSTO to develop mutually beneficial collaborations.

Interaction in regard to ANSTO's commercial activities is facilitated by Access ANSTO

Deliver excellence in nuclear science and technology



ANSTO will be the source of significant new discoveries, producing new knowledge, capabilities and technologies. While some of these will be applied to our own operations, others will be developed through targeted research, with the benefit distributed widely by outreach activities which encourage adoption and commercialisation.

Since 1958, Australian scientists and engineers have used ANSTO's nuclear facilities and expertise to increase our fundamental scientific knowledge and assist national industries. Their efforts have produced benefits in many areas that are essential to Australia's future, including agriculture, manufacturing, minerals, construction, human health and the environment.

In fact, nuclear science and technologies are useful in so many different areas that it's quite a challenge working out which areas are the best for ANSTO to concentrate its efforts in. But that's exactly what we are doing.

We are putting more resources into areas where we know ANSTO's expertise is truly world-class and where Australia really stands to benefit from new knowledge, capabilities and technologies. Australia's new research reactor, OPAL, will further strengthen our nuclear science and technology capabilities.

Our main targets include developing new radiopharmaceuticals for better diagnosis and treatment of cancer, and using naturally occurring isotopes to study environmental processes and climate change. We are developing advanced materials for high-tech industrial applications – as well as for everyday life. Our scientists are devising new and better ways of measuring the impact that radiation has on our bodies and using neutrons and X-rays for scientific research that will expand the boundaries of human knowledge.

And because people are ANSTO's – and Australia's – greatest resource, we are increasing our emphasis on staff training and collaboration with other national and international research agencies for the benefit of people right across the globe.

Deliver excellence in nuclear science & technology

Dr Shane Kennedy says that great scientific discoveries and innovations require the latest technology operated by highly skilled and highly motivated scientists and professional staff.

"At ANSTO, we are bringing together everything we need to deliver excellence in nuclear science and technology for Australia and for our partners from around the world.

"My team is building highly specialised scientific instruments that will use neutron beams from the new OPAL research reactor to study many different kinds of materials. And we are boosting our in-house talent by recruiting the world's best scientists to help us make the most of our new facilities."

Killing cancer, saving lives

Every year, around 36,000 Australians die from cancer, despite our high standards of medical care.

All cancer cells have one thing in common. They have lost the instructions that tell them when to die. One of the ways our bodies keep healthy is for old cells to die and new cells to take their place. This process is called apoptosis, programmed cell death, sometimes known as 'cell suicide'.

Medical specialists treat cancer by using drugs (chemotherapy) or radiation (radiotherapy) to convince cancer cells to undergo apoptosis. But because doctors can't see how quickly the cancer cells are dying, or if they are dying at all, it is difficult to design really effective treatments with minimal side effects.

Scientists from ANSTO and the University of New South Wales (UNSW) have developed a new, non-invasive way to look at cancer cells. UNSW scientists made a chemical compound that attaches itself to cells undergoing apoptosis. ANSTO tagged the compound with radioisotopes so they could track it through the body. Doctors will be able to use the tagged compound agent to check the effectiveness of a patient's treatment.

Radiopharmaceutical imaging can also help medical scientists develop treatments for other diseases in which cell death is premature and haphazard, such as dementia, stroke, Alzheimer's and heart attacks.

"The techniques we're working on are really powerful. Radiopharmaceuticals are helping to make cancer treatments more effective as well as contribute to the development of new treatments for other major health conditions such as Alzheimer's and heart attacks."

Dr Nabil Morcos, ANSTO radiopharmaceuticals scientist

"I really care about my work. I want to do the best job that I can. To me that means demonstrating competence and professionalism in everything I do."

Dr Zhaoming Zhang is a physicist. Her work requires a thorough understanding of the fundamental science behind the physical properties of many different materials. Zhaoming uses high-tech research facilities in Australia and overseas to study the advanced new materials that ANSTO develops.

"ANSTO's ability to contribute to Australian and international science and technology depends on the dedication of our staff. I'm proud to be part of that effort."

case study

Cosmic quest for safer radiation

Here's a good question for your next trivia night: what do astronauts and cancer patients undergoing cancer therapy have in common? Answer: they are both exposed to higher than normal levels of radiation.

Radiation therapy aims to destroy cancer cells (tumours). If the radiation reaches parts of the body outside the tumour, patients can suffer unwanted side effects. Although these unwanted effects are outweighed by the urgent need to destroy the cancer, radiation specialists want to find ways to minimise side effects without reducing the effectiveness of radiation treatments. To do this, they need to know how radiation affects the body at the level of individual cells, which means looking at samples around the size of a micrometre (a thousandth of a millimetre).

ANSTO researchers are working with the University of Wollongong's Centre of Medical Radiation Physics to improve and find new uses for a miniature device called a microdosimeter that can measure radiation effects at the cellular level. They are also developing a new device that can look at radiation effects in even greater detail.

The microdosimeter will also enable researchers to investigate the use of proton therapy, a cancer treatment not yet available in Australia. Protons are one of the three kinds of fundamental particles found in atoms, the other two being neutrons and electrons. Conventional radiotherapy using X-rays or electrons can damage healthy tissue outside tumours, causing side effects such as extreme nausea and weakness. Proton therapy is much more accurate, reduces side effects and means that many patients can leave hospital straight after treatment.

The downside is that protons interact with cells in a much more complex way than X-rays and electrons. Proton therapy must be carefully planned so that proton beams with the appropriate energy enter the patient's body at just the right angle. Researchers will use the microdosimeter to see how protons interact with living cells. Their findings will be combined with information from computer modelling studies to enable radiation specialists to plan more precise and effective proton treatments to complement conventional radiotherapy.

Out in space, intense cosmic radiation can cause fatigue, hair loss, cancer and damage to the central nervous system. To ensure that astronauts do not suffer any serious problems from radiation exposure during their space missions, researchers want to know exactly how this radiation affects astronauts' bodies.

ANSTO and the Centre of Medical Radiation Physics are helping the NASA space program investigate how microdosimeters could play a part in protecting astronauts from space radiation. Microdosimeters tested by the Australians will be launched on board a US Naval Academy satellite in 2007.

"It's a great feeling to be part of a team that is contributing to international space programs as well as working towards improving the health of Australian cancer patients."

Dr Mark Reinhard, ANSTO materials scientist

Something to Bragg about

In 1915, the year that Australian troops fought at Gallipoli, father and son team William and Lawrence Bragg became Australia's first winners of the Nobel Prize for Physics. The Braggs received the prestigious international award for their work in founding a new branch of science. They were the world's first scientists to successfully use X-rays to study the regular internal structure of crystals.

In 2002, ANSTO established the Bragg Institute to maximise scientific use of neutrons from HIFAR and to best utilise capabilities of the new OPAL reactor.

The Bragg Institute leads Australia in using neutrons and X-rays to solve complex research and industrial problems in many important fields. These complementary techniques are valuable tools for investigating molecular structures and properties.

Bragg Institute staff study materials by bombarding them with neutrons and X-rays, which make patterns when they bounce off the atoms in the materials. By analysing these patterns, we can obtain information about where the atoms are located in a particular material, how they are connected and how they move.

Atoms contain three types of fundamental particles: neutrons, protons and electrons. The properties of neutrons make them useful for studying atomic and molecular structures ranging in size from one nanometre (one millionth of a millimetre) to several hundred nanometres.

Neutrons have no electric charge, so they can reveal the position of the nucleus itself, which makes up a tiny fraction of the volume of an atom. X-rays are scattered by electrons, so they reveal the position of the electron clouds around the nucleus.

As neutrons are highly penetrating they make it possible to study samples deep inside large pieces of equipment (such as aircraft engines), and inside vessels that have different conditions of pressure, temperature and environment.

They also behave like tiny bar magnets, which means they can be used to investigate the magnetic properties of materials such as superconductors and computer hard-drives.

In a world of increasing technological complexity, Australia's future depends in many respects on our understanding of the detailed physical and chemical properties of materials. Neutrons offer an important way to enhance this understanding, and OPAL will provide neutron beams for some powerful and versatile scattering techniques.

ANSTO will also continue to use our own X-ray facilities as well as overseas facilities and the Australian Synchrotron being built in Melbourne.

"In my work at the Bragg Institute, I help scientists and engineers from around the world use our instruments to achieve their research goals. Looking after visiting researchers with different needs and levels of expertise is a challenge I really enjoy."

Dr Jamie Schulz, ANSTO neutron scattering scientist

case study

Cool new process gets tough with sunglasses

You’ve just dropped your brand new sunnies and there’s a big scratch right across the lens. Don’t you wish someone would hurry up and invent armour-plated sunglasses?

Plastics used in sunglasses and some reading glasses are lightweight and stylish, but they are soft and easily scratched. A thin surface coating of titanium dioxide would do the trick, but you need to design the coating so it has the right optical properties.

ANSTO’s Gerry Triani and his colleagues have developed a method of applying multiple layers of titanium dioxide and aluminium oxide to plastics and other materials with precision control. And unlike some commercial processes, their method works at temperatures that won’t make your shades lose their cool!

The process involves placing the plastic or other surface in a vacuum chamber and using a series of chemical pulses to build up the layers atom by atom. Because of the exquisite level of control provided by the technology, the thin films follow the precise shape of the underlying surface and do not have the tiny pin holes that other methods can produce. Gerry’s group are also using their knowledge of how thin films grow to help develop other applications with industry partners, including the production of flexible solar cells.

“By working with university researchers and commercial companies, we can explore the science as well as find new applications for a technology that was originally designed for making very small electronic circuits.”

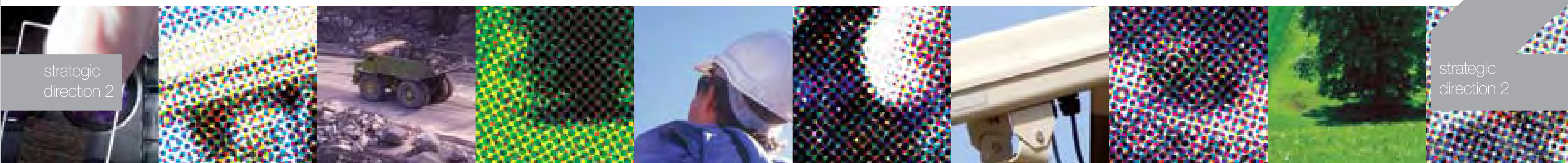
Gerry Triani, ANSTO materials scientist

strategic direction 2

Focus our capabilities to support issues of national importance

We will focus our facilities, activities, expertise and collaboration on areas that contribute to Australia's priorities, especially in support of its nuclear, research, industry, environmental, health, security and international relations policies.

Focus our capabilities to support issues of national importance



ANSTO and Australia both have important roles to play in the 21st century. Australia's role is not simply to improve the well-being of its people, although this is clearly essential. Our nation has a responsibility to contribute to regional and global initiatives that aim to make the world a safer place in which to live – to harness the power of nuclear science and technology without exposing ourselves to unnecessary risks.

We use our nuclear expertise and unique high-tech facilities to support Australia's nuclear, research, industry, environmental, health, security and international relations objectives. We provide advice to the Australian government to assist it in making decisions on a range of issues, including climate change, power generation, and counter-terrorism.

Nuclear technology is providing information that will help our nation to make best use of its precious water resources, and help the mining industry minimise its environmental footprint. Our expertise is also supporting the development of innovative new Australian businesses.

In terms of Australia's international role, ANSTO participates in national and international programs that make it easier for a range of countries, especially those in the Asia-Pacific region, to gain the benefits of nuclear science and technology. We also contribute to the expertise these countries have in managing radioactive materials.

Dr Ron Hutchings has a great nickname. Because he coordinates the NICE program for ANSTO, his workmates call him 'the nice manager'.

In fact Ron's position addresses two very important issues for the future of ANSTO and Australia. NICE stands for National Interest and Capability Enhancement.

"Part of my job is to help focus ANSTO's capabilities to support issues of national importance. This involves bringing staff together from all over ANSTO to work on major issues such as counter-terrorism.

"I also work with other research agencies and government departments to meet Australia's national research needs without costly duplication of effort."

The Bali bombings, terrorist attacks in London and the events of September 11, 2001 in the US have illustrated the reality of global terrorist activity. Now we know all too well how the safety of ordinary citizens can be seriously threatened by the actions of terrorist groups.

Although terrorist groups continue to use conventional weapons, such as explosives, some experts believe that it is possible that some groups may be considering using nuclear or radioactive materials. With some effort, these materials could conceivably be transformed into 'dirty bombs'. These devices have the potential to disperse radioactive materials.

To combat this threat to global security, the international community is taking steps to improve its ability to detect and recover illicitly trafficked radioactive and nuclear materials. ANSTO is using its knowledge of nuclear science and technology to assist several international counter-terrorism initiatives.

For example, ANSTO scientists have been evaluating the performance of hand-held analysers that can identify particular radioisotopes. Border guards, customs officials, quarantine authorities and police routinely use such devices to help them stop illegal radioactive and nuclear materials being smuggled across borders.

In safe hands

Hand-held analysers are mainly used to identify which particular radioactive or nuclear material is present in a vehicle or cargo that has already been identified as carrying radioactive material. Because they may be used to scan large numbers of objects and people every day, hand-held analysers must be robust, easy to use, fast and accurate.

ANSTO is testing new materials from which to build even better radiation detectors. Thinking like those with ill-placed intentions, the ANSTO team considered ways of masking the unique gamma-ray signals produced by illicit radioactive and nuclear materials, such as hiding them in a legal shipment of radioisotopes. Then they had to develop ways to find these masked or hidden materials. Their efforts will help customs officials and other policing agencies develop more effective detection and response strategies.

"It wasn't what I expected to be working on as a physicist at ANSTO, but I enjoy the challenges and rewards associated with helping to strengthen international security."

ANSTO scientist

Looking after ore bodies

Australia has the world's biggest uranium reserves. As the world's second-largest uranium producer, Australia must ensure that its uranium mining operations do not damage the natural environment. In achieving this goal, our mining companies and scientists have gained valuable experience in dealing with sensitive environmental issues.

Over the last 30 years, ANSTO has carried out studies at all of Australia's operating uranium mines as well as contributing its expertise to international agencies.

In the 1970s and 1980s, ANSTO helped solve a serious environmental problem at the abandoned mine workings at Rum Jungle in the Northern Territory. In those days, it was common practice in open-cut mines to reach the main ore body (uranium or other valuable minerals) by removing the overlying dirt and rocks and dumping these in a large pile ('overburden'). ANSTO found that iron minerals in the overburden were reacting with oxygen and water to produce acid that helped dissolve other minerals and led to pollution problems in nearby rivers and groundwater. ANSTO's solution was to cover the Rum Jungle overburden with three different layers of soil and grow plants on the top to reduce erosion.

ANSTO also has expertise in the treatment of uranium and other ores. The Nabarlek mine, which operated in the 1980s, processed its uranium with the help of an innovative, non-polluting oxidant developed by ANSTO's Bob Ring and his colleagues.

After the Berlin Wall fell in 1989, ANSTO was asked to assess the treatment of flood water from the Ronneburg uranium mine and mine water from the Konigstein plant. Both these East German sites were being decommissioned and ANSTO provided valuable advice to assist long-term planning for their management and rehabilitation.

Today, Bob Ring and his team of 30 scientists and engineers continue to work closely with Australia's uranium mining companies. In addition to helping ensure the safety of the natural environment around our uranium mines, Bob's team works with the mining companies to reduce their use of water, which is Australia's most precious natural resource.

For example, ANSTO has worked closely with Energy Resources of Australia to develop a process for treating some of the water used at the site of the Ranger uranium mine in the Northern Territory. Because the treated water will be discharged to an environmentally sensitive area, the process must produce water of a very high quality. A $28 million water treatment plant is expected to begin operating in 2006.

"International acknowledgement that overuse of fossil fuels is affecting the earth's climate has revived interest in nuclear power and uranium mining in Australia. Our team at ANSTO has the expertise to ensure that any new developments meet strict environmental standards."

Dr Bob Ring, General Manager
ANSTO Minerals

Putting water management on firm ground

Good, clean water is Australia's most precious natural resource, but recent droughts and changing rainfall patterns have increased the need for water restrictions and water recycling. Water authorities are looking for reliable sources beyond our dams and waterways.

The Sydney Basin, which extends from Newcastle to Jervis Bay and west to Lithgow, contains enormous quantities of water trapped in sandstone aquifers deep below the ground. ANSTO and the University of Wollongong are using nuclear techniques to find out more about this valuable water resource – and to ensure that it is not over-exploited.

To help assess potential drilling sites, ANSTO's Chris Waring injects 'tracers' such as salt (sodium chloride) to see how permeable the sandstone is at a particular site and how quickly water can be extracted. The best sites are those with good storage capacity and efficient flow rates.

Chris is also looking at long-term changes in the tiny quantities of naturally occurring radioisotopes found in groundwater. Careful interpretation of the results can provide important information about the age and origin of the water. If water has taken thousands of years to filter through the sandstone to reach a particular site, then we must use it with care.

"We're gradually building up a very complex picture and getting a few little surprises along the way to change our ideas about the nature of the water resources hidden away in Sydney Basin sandstone."

Dr Chris Waring, ANSTO environmental scientist

Dr Chris Barbé believes success in scientific research depends on many factors: hard work, perseverance, an open mind, innovation, collaboration, responsiveness to others and the ability to get people working together to achieve a common goal.

Chris is helping to make medical treatments more effective. But instead of creating new drugs, he is developing new ways to deliver them to specific parts of the body.

In collaboration with clinicians and industry partners, Chris is fine-tuning his innovative CeramiSpheres (tiny particles containing active ingredients inside a 3-D silica lattice) so they can evade the body's natural defences and deliver their contents right on target.

case study

Before the development of modern radiotherapy machines, highly radioactive sources were used to produce the intense radiation needed for cancer treatment. Unfortunately, in some countries, these old sources have not always been well managed and if they fell into the wrong hands could seriously threaten health and safety.

Other radioactive sources, for example those used in industrial gauges, might be as small as a headache tablet, but could cause more than a few headaches if combined with conventional explosives to make a 'dirty bomb'.

ANSTO is playing a major role in an international counter-terrorism initiative. Allan Murray and his colleagues are working with other agencies to identify and manage the risks associated with using radioactive sources in medicine, industry, agriculture, engineering and oil exploration in South East Asia.

So far they have spent more than 1 200 hours helping to ensure the safe use, management and control of radioactive sources in Indonesia, the Philippines, Papua New Guinea, Brunei, Singapore, Laos, Cambodia and Vietnam.

Lending a hand to our neighbours

"When my colleague explained that the most important part of the radiation monitoring equipment we were demonstrating was the person operating it, the Vietnamese participants in our training workshop immediately understood what we were on about."

Allan Murray, ANSTO project leader

strategic direction 3

Maximise return on investment in expertise and specialised facilities

strategic direction 3

Maximise return on investment in expertise and specialised facilities

ANSTO will operate world-class nuclear facilities at a level of efficiency that ensures a high return on investment for the Australian Government, our customers and our collaborative partners.

ANSTO has an enviable track record in using its expertise and specialised facilities to provide tangible benefits to both community and industry, particularly in the health sector.

The Australian government has acknowledged ANSTO's contribution to national research efforts and the economy by investing $360 million in the construction of the OPAL research reactor and associated scientific instruments. Other groups that have invested in ANSTO include commercial companies, environmental management agencies, medical research organisations and industry. The National Science Council of Taiwan has acknowledged the regional importance of the OPAL reactor and the Bragg Institute, striking an $8.5 million deal to install and operate a unique instrument called a cold-neutron 3-axis spectrometer.

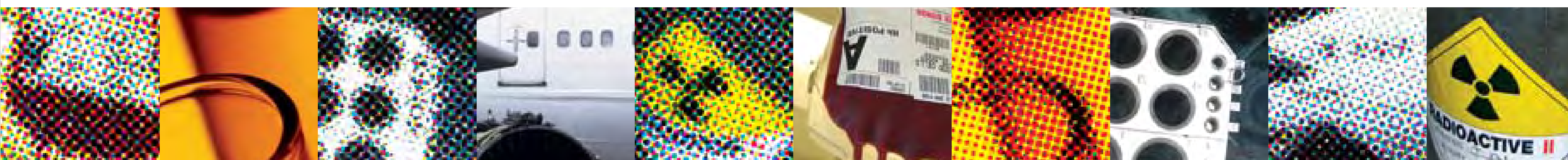
Safety, security and environmental sustainability are essential elements of all ANSTO activities, particularly when it comes to handling hazardous materials.

Safe management of radioactive waste is a tough job, but somebody has to do it. At ANSTO, that somebody is **Lubi Dimitrovski.**

Lubi leads a team of more than 30 highly specialised staff who safely collect, process, package and store radioactive waste from ANSTO's radioisotope manufacturing operations and scientific research programs.

"My job is to ensure that ANSTO handles its radioactive waste in a way that meets strict regulatory and environmental requirements as well as living up to community expectations."

strategic direction 3



The OPAL research reactor will enable ANSTO to repay the nation's faith in us by assisting researchers from across Australia who are using neutron scattering to solve a wide range of problems as well as enhancing our own research capabilities and scientific expertise. It will substantially increase ANSTO's production capacities, enabling us to provide a greater number and wider range of radioisotopes and irradiation services.

We will also increase our efforts to commercialise the technologies and expertise we have developed and to attract new users who can share the benefits, as well as generate new revenue streams for the Australian economy and create more jobs.

By evaluating our performance and comparing ourselves with similar organisations around the world, we will continue to operate efficiently, effectively and securely while safeguarding the well-being of staff, the community and our natural environment.

Crocodile blood could save lives

Never mind the crocodile tears, it's crocodile blood that's worth bottling!

When crocodiles make headlines it's not usually for good news reasons, but that could be about to change. Australia's most notorious predator may hold the secret to making artificial human blood.

Do we need a substitute when there seems to be so much of the real stuff around, particularly if you watch vampire movies? The answer is yes. Artificial human blood could be invaluable for some kinds of major surgery as well as helping to ensure that the blood banks never run short, especially in developing countries.

ANSTO's Kerie Hammerton and Chris Garvey – and their colleagues from the University of Sydney – are looking at crocodile red blood cells, which carry oxygen around the body inside molecules of a special protein called haemoglobin. Human red blood cells also use haemoglobin to carry oxygen around our bodies, but there are important differences.

Red blood cells make up half the volume of human blood, but only one-fifth the volume of crocodile blood. And yet crocodile blood is just as efficient at getting oxygen from the lungs to the muscles. Working muscles, such as those a crocodile uses to cruise across a billabong to nab an unwary swimmer, need both energy and oxygen.

In humans, the signal for red blood cells to release oxygen is governed by a complex biochemical pathway. Crocodiles use nothing more than the carbon dioxide produced by working muscles. The carbon dioxide weakens the ties that bind oxygen to crocodile haemoglobin, releasing more oxygen for the crocodile's muscles to use.

In their bid to reveal the crocodile's innermost secrets, the scientists are using some sophisticated techniques to see what is happening in living cells. One tool, called neutron scattering, lets them pinpoint where the haemoglobin is located inside the cells.

And the key to making artificial human blood? The basic idea is to develop a haemoglobin solution that does the same job as blood, but without the added complexity of packaging the haemoglobin into cells.

Using human haemoglobin to make artificial blood creates problems because haemoglobin molecules that are outside red blood cells tend to break up into smaller bits, which can damage the kidneys. That's where the crocodiles come in. Using neutron scattering, ANSTO has shown that crocodile haemoglobin molecules can link together, forming haemoglobin balls which do not enter the kidneys.

"The breakthrough for me was when I realised that haemoglobin was one of the main reasons why crocodile blood behaves so differently from ours. That realisation is now leading to all kinds of fascinating and useful discoveries."

Dr Kerie Hammerton, ANSTO environmental scientist

case study

Science fantasy becomes a reality

In the 1960s sci-fi movie *Fantastic Voyage*, screen siren Raquel Welch stars as a member of a surgical team that is miniaturised and inserted into the bloodstream of a dying man in a desperate attempt to save him.

Forty years later, we may not be able to miniaturise our medical specialists, but we can buy an increasing range of medicines and health foods with tiny particles that slowly release their active ingredients into our bodies. However, unless these active ingredients can somehow slip past our immune systems, they may be destroyed by our own natural defences before they can reach their intended destination inside our bodies.

That's where ANSTO's Chris Barbé and his team enter the picture. They are making tiny particles that contain the active ingredient – whatever that might be – inside a 3-D silica lattice with holes just the right size to let the contents escape at the required rate. The particles range in size from one tenth of a millimetre in diameter to around 10 nanometres, which is ten thousand times smaller than the width of a human hair. The sneaky part is that the silica particles can be made so that our immune system doesn't recognise them as foreign – and therefore doesn't tag them for premature destruction.

Making the particles is a bit like mixing salad dressing with vinegar and oil and the particles forming inside the droplets of vinegar. Altering the recipe alters the properties of the silica particles. For example, changing the size of the vinegar droplets changes the size of the silica particles. Changing the acidity of the emulsion changes the size of the holes in the silica lattice, enabling the particles to be tailor-made for releasing a particular active ingredient.

Called 'CeramiSpheres', the silica particles can potentially contain all kinds of active ingredients, not just medicines. While they will undoubtedly deliver plenty of medical benefits to patients in Australia and around the world, the team has also had enquiries from companies interested in using CeramiSpheres to release enzymes in washing powder, flavours in foods, oils in perfumes and biocides in paint. CeramiSpheres could even have potential for treating scars on burns victims.

As someone famous may once have said, the future is limited only by our imagination.

"I was listening to other scientists talk about the problems they were having with tiny particles that slowly lost their contents, when I realised that what they saw as a problem could be turned into an advantage."

Dr Chris Barbé, ANSTO materials scientist

strategic direction 3

"My team works hard to keep the reactor operating safely, efficiently and reliably. That's how we achieve maximum return on Australia's investment in our expertise and specialised facilities."

Dr Greg Storr is in charge of Reactor Operations at ANSTO. His job is to ensure the smooth running of the nation's first nuclear reactor, HIFAR, and to bring the new OPAL research reactor safely up to speed when the time comes.

"The new reactor will have a much higher capacity for scientific research, radioisotope production and industrial applications. That means we will be able to find new ways to produce benefits for Australia."

case study

Whilst most of us are aware of the benefits electricity brings to our lives, we don't usually consider the vast infrastructure that helps generate this power.

The components which comprise the power generation facilities go through considerable stress and strain when they are being manufactured, via methods such as welding and forging. Neutron beams offer a unique way to understand these materials, and allow us to know whether they can continue to be safely used or need to be replaced.

Most of the electricity that powers Australia is generated by steam turbines with metre-long blades that whirl around at close to the speed of sound.

At this speed, the tiny drops of water that condense from the steam can strike the blades with enough force to damage the surface of the blade tips. A single blade is worth $10 000-$15 000, so replacement costs can quickly run into millions of dollars.

A new repair method developed by the Cooperative Research Centre for Welded Structures uses laser technology to coat the blade edges with a hard-wearing metal alloy made of cobalt and chromium. However, ANSTO's neutron beam 'strain scanning' equipment and complementary X-ray techniques revealed that the coating process itself was creating potentially damaging stresses in the turbine blades.

The problem was solved by a post-welding heat treatment, which minimised residual stress in the repaired section of the blades, thereby reducing the potential for premature blade failure.

"I get a lot of satisfaction out of using cutting-edge technologies to solve real world problems. Neutron beam instruments provide information you just can't get any other way."

Dr Phil Bendeich, ANSTO materials scientist

Lasers provide powerful stress relief

strategic direction 3

Our new world-class nuclear research reactor, OPAL, will strengthen Australia's ability to develop and apply new knowledge in many important areas, including agriculture, aerospace, manufacturing, mining, construction, food science, human health and the environment.

OPAL plays a key role in providing high-quality radiopharmaceuticals for nuclear medicine, irradiating silicon for advanced electronics applications and producing radioisotopes for environmental, industrial and scientific uses. OPAL will enhance ANSTO's ability to undertake neutron scattering science. This unique scientific discipline increases our fundamental knowledge of materials, thereby assisting our industries.

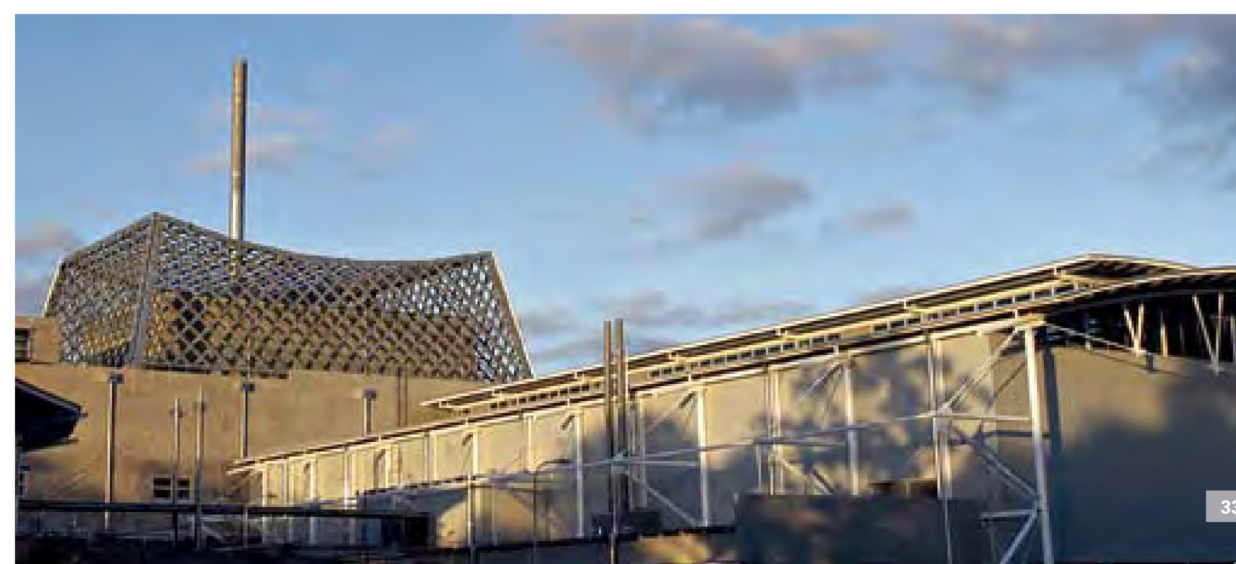
The new reactor and its complementary world class neutron scattering facilities will attract many of the world's best scientists to ANSTO to collaborate with our people. This will further enhance the country's scientific reputation.

OPAL will replace Australia's first nuclear reactor, HIFAR, which is approaching the end of its operating life and cannot match the performance of modern reactors.

The new reactor is water-cooled and uses low enriched uranium fuel. OPAL's performance means it will rank among the best of the world's existing 250 research reactors.

Construction is scheduled for completion in 2006 and OPAL is expected to commence operating at full capacity in 2007.

OPAL: a new gem in Australia's scientific crown



case study

The ultimate lock-up solution

Radioactive materials have provided many benefits over the last 50 years, but have also been used for less altruistic purposes. One challenge faced by our generation is dealing with the inherited waste arising from less than ideal past waste management practices.

Since the late 1970s, ANSTO scientists have devised various methods for immobilising radioactive wastes based on 'synroc' (synthetic rock), which was originally developed by researchers at the Australian National University. Synroc mimics mineral formations in the earth's crust that have kept naturally occurring radioactive materials locked up for billions of years.

Recently, ANSTO was asked to address a particularly challenging problem: to develop a means of locking up very impure plutonium waste that had been stored in the United Kingdom for 50 years. UK scientists had already shown that the waste was unsuitable for recycling and could not be immobilised by their existing methods.

ANSTO's solution imprisons the plutonium and other impurities in a dense insoluble synroc matrix. Like natural rocks, the synroc is formed under pressure and at high temperatures (1 200ºC).

UK nuclear agencies are very happy with the results. They are presently building a full-scale non-radioactive plant to demonstrate the process, which has the potential to save the UK billions of dollars in waste treatment costs.

"The UK authorities challenged us to solve what they thought was an intractable nuclear waste problem – and we succeeded! Now this great Australian technology is about to realise its potential after more than 20 years of research."

Dr Bruce Begg, ANSTO materials scientist

strategic direction 4

Promote understanding of the benefits of nuclear science & technology

Promote understanding of the benefits of nuclear science & technology

Through effective communication and engagement with industry and wider communities, we will increase support for our work and encourage the further adoption of applications of nuclear science and technology.

The full potential of ANSTO's specialist nuclear facilities and expertise can only be realised through the involvement of external groups such as research organisations, government agencies, commercial companies and community groups. Whilst positive work has been done in this area, there are expectations on us to improve our performance as well. Considering we are primarily a taxpayer-funded organisation, these expectations are entirely appropriate and we are seeking to exceed them.

The instigation of Access ANSTO (see page 4) – our business development portal – is one part of the story; the interaction via tours, briefing papers, presentations and parliamentary reports with government is another. The Australian community is an especially important stakeholder group, and a great deal of energy is focused not just on making people aware of the benefits of our work, but to encourage them to become advocates for it.

We are mindful that each stakeholder group has unique needs and challenges, and we are tailoring our communication and services in order to create meaningful, sustainable relationships with these groups. Additionally, we continually work to strengthen our networks within the national and international scientific communities. This will help maintain the world-class standard of our research efforts.

Closer to home, we work hand-in-hand with industry organisations and commercial companies to devise new technologies, products and services utilising our scientific knowledge. This collaboration and cooperation enmeshes ANSTO staff within the diverse industries to which our science makes a tangible contribution; this is essential in maintaining our technological leadership in Australian industry. It also contributes to a vibrant, innovative internal culture, one geared towards addressing client and collaborator needs.

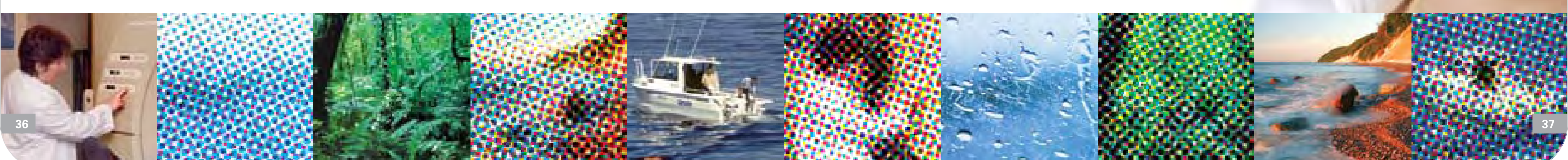
Reflecting both the humanitarian value of existing nuclear health and medical techniques, and the potential for further advances, we maintain ongoing relationships with medical practitioners and recipients of nuclear medicine and radiotherapy.

And perhaps most importantly of all, in order for our goal of building durable relationships with stakeholders to be realised, we are making a significant effort to give Australia's younger generation a broad knowledge of the applications and issues relevant to nuclear science and technology. This means reaching out into schools, and encompasses both the provision of a range of education resources and giving assistance to science teachers nationally.

"My job's great! I get to tell people about the amazing science being undertaken by ANSTO's passionate and dedicated scientists."

Martha Halliday and her team of five education officers work with high school teachers across Australia. They provide resources to help teachers present nuclear science topics as part of the junior science syllabus and for senior-level physics and chemistry. As part of her efforts to promote understanding of the benefits of nuclear science and technology, Martha also organises talks and tours for members of the public.

"People always tell me they had no idea how important ANSTO's work is, or in how many areas we assist Australian industry."



Radiopharmaceuticals: diagnosing and destroying cancer

In Australia, one in three men and one in four women will be affected by cancer before the age of 75. So the odds are that we will all know someone diagnosed with cancer, even if we escape it ourselves.

Each year in Australia, more than 88 000 new cases of cancer are diagnosed, yet more than half of those cases will be successfully treated.

The survival rate for many cancers has increased by more than 30 per cent in the past two decades. This can be explained by better diagnosis and treatment, said Associate Professor Paul Roach, Director of the Nuclear Medicine Department at the Royal North Shore Hospital in Sydney.

"The most common cancer treatments are surgery, chemotherapy and radiation therapy," he explained.

Internal radiation therapy is a treatment method using a radiopharmaceutical, which is delivered to the affected organ(s). (A radiopharmaceutical contains radioisotopes, unstable atoms that regain stability by shedding radioactive energy.) After it is administered, the radiopharmaceutical is taken up by the targeted organ. Another method is to attach the radioactive element to a biological compound, which lodges in the body at the disease site.

"Thyroid problems such as cancer and hyperthyroidism (an overactive thyroid) can be diagnosed and treated with radioiodine," Dr Roach said. "The thyroid gland concentrates iodine, so by ingesting a radioactive iodine-131, many thyroid tumours can treated. More recently, cancers of the liver, bone, bowel and adrenal glands are being treated with similar tumour-seeking radioactive compounds."

Radiopharmaceuticals for imaging

"In nuclear medicine, we use several techniques for diagnosis of various clinical conditions," said Dr Roach. "These include the use of reactor-produced radiopharmaceuticals to allow us to diagnose conditions such as clots in the lungs, fractures or cancer in bones, blockages in the coronary arteries of the heart, nodules in the thyroid gland, obstruction or abnormal function of the kidneys, and the spread of breast cancer to lymph nodes, to name a few.

"For many of these types of imaging studies, we use three dimensional imaging with a technique called SPECT (single photon emission computer tomography). More recently, a limited number of centres have been funded to provide positron emission tomography (PET) scanning, which produces images of blood flow and other biochemical functions, particularly using a radioactive glucose analogue to assess the extent of cancer within the body. PET radiopharmaceuticals are produced in cyclotrons."

While most nuclear medicine techniques are used for diagnosis, radiopharmaceuticals can also be used for therapy.

In relation to thyroid cancer, more than 4 600 patients receive ANSTO manufactured radioiodine each year in Australia. After patients have their thyroid surgically removed, the radioactive isotope is administered as a single capsule. This is usually well tolerated by patients with the majority having relatively few, if any, side effects. Any normal or cancerous thyroid cells remaining after the surgical procedure absorb and concentrate the iodine and are destroyed. Most patients are cured after only one dose (or sometimes two) of radioactive iodine-131.

The success rate for differentiated thyroid cancer is extremely good with 10 year survival rates of over 90% often reported. Once cured, patients undergo periodic radioiodine scans and blood tests for surveillance but they typically live normal and healthy lives.

Water sheds new light on climate change

Gases produced by human activity are changing the way our atmosphere behaves – and the earth is gradually warming up as a result. Sometimes called the greenhouse effect, this climate change will be a major problem if we can't find ways to 'keep our cool'.

Computer models designed to help us understand and predict climate change suggest that large-scale destruction of forests reduces rainfall, which in turn reduces the amount of rainwater available for river flows or for use by plants and people.

Each water molecule consists of two hydrogen atoms and one oxygen atom joined together. Because there are different kinds of hydrogen and oxygen atoms, called isotopes, there are also different kinds of water. Isotopes are atoms of the same element, such as hydrogen, that have different weights.

In nature, about one in every 500 water molecules has one of its ordinary hydrogen atoms replaced by a heavier hydrogen atom. One in every 6 500 water molecules has an oxygen atom that is heavier than ordinary oxygen.

These rare water isotopes are slightly heavier than normal water molecules, so they evaporate less easily. This means raindrops that contain water evaporated from rivers have less of the rare water isotopes than the rivers did. But plants do not distinguish between the different water isotopes. When their leaves transpire (water vapour escapes through tiny openings in the leaves), the water evaporates and turns into raindrops that have more of the rare water isotopes than raindrops that contain water evaporated from nearby rivers.

In the Amazon basin, water that evaporates from the tropical Atlantic ocean is blown by the wind up the Amazon river towards the Andes mountains. Several times on its journey, this water falls as rain, evaporates from the ground or from leaf surfaces and then falls as rain again, in a process called water cycling.

ANSTO's Ann Henderson-Sellers, and researchers from the University of Technology, Sydney are using rare water isotopes to look at water cycling in large water basins such as the Amazon and the Murray-Darling.

They found that rainwater from the Amazon and Andes in the 1990s and 2000s had less of the rare water isotopes than rainwater samples taken in the 1970s. This suggests that less of the more recent rain came from water transpired from trees – and provides the world's first independent evidence of the reduced water cycling predicted by the computer models.

"It is amazing to me that such a simple and well known formula 'H2O' can reveal such intricacy and scientific insight."

Prof Ann Henderson-Sellers,
ANSTO environmental scientist

Nipping algal blooms in the bud

Shellfish can be a luxury or a staple food, but no-one wants to suffer from the shellfish poisoning caused by toxic algal blooms.

An algal bloom or red tide is a massive population explosion of tiny algae that can contaminate shellfish with a toxin that affects the human nervous system. The resulting paralytic shellfish poisoning affects 60 000 people a year, and can be fatal.

Manila Bay in the Philippines is home to a large shellfish industry, as well as being a very busy port and the nation's capital, home to 16 million people. Untreated sewage and agricultural fertilisers flow into the rivers around Manila Bay, providing nutrients to feed algal growth.

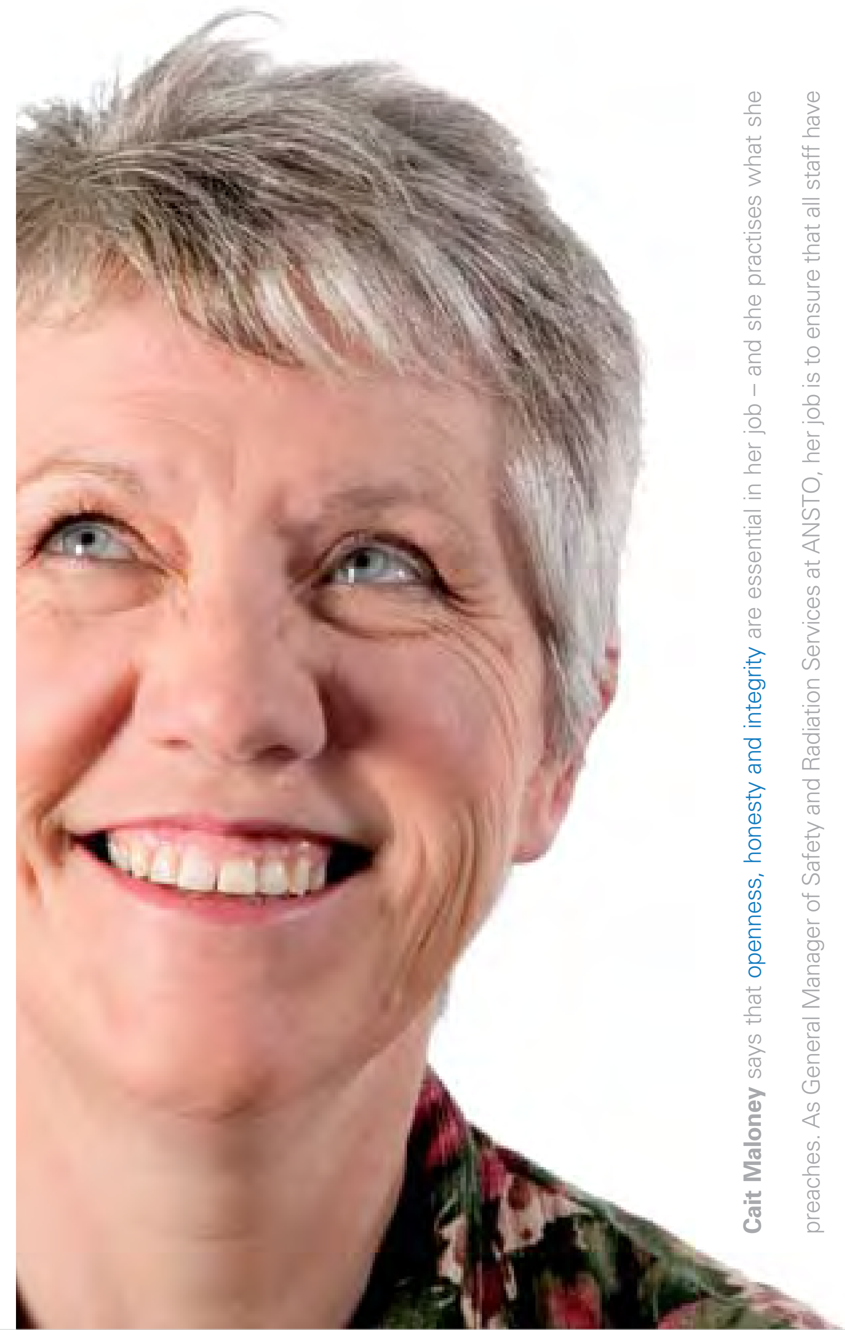
ANSTO and the University of New South Wales are helping to improve predictions of when and where algal blooms could occur. One approach involves creating computer models that predict the movement of nutrients and algae.

ANSTO's Cath Hughes tested a Manila Bay model developed by UNSW. Working with the Philippines Nuclear Research Institute, Cath released a short-lived medical radioisotope tracer (technetium-99m) into Manila Bay. Technetium-99m has an 'activity' well below naturally occuring background radiation. By monitoring the plume of radioactivity the researchers were able to map how the water moved around the bay.

The model matched the real world, so it can now be used to predict where sewage and other contaminants end up in Manila Bay. This knowledge will contribute to strategies that can be developed to manage the problem.

"When I saw young children playing in rubbish and filthy sewage-contaminated water in the Pasig River, I realised that their futures and the livelihoods of their families are bound up with the future of Manila Bay."

Dr Cath Hughes, ANSTO environmental scientist



Cait Maloney says that openness, honesty and integrity are essential in her job – and she practises what she preaches. As General Manager of Safety and Radiation Services at ANSTO, her job is to ensure that all staff have a safe workplace and do not put the environment at risk.

"We talk to all our staff about the risks they face in doing their jobs safely and we give them the information they need to be able to handle those risks," Cait said. "We also encourage them to tell us their ideas about better ways of doing things at ANSTO."

case study

Circulating in Darwin's footsteps

In 1836, Charles Darwin collected coral specimens from the Cocos (Keeling) Islands, an isolated tropical atoll near Java in the Indian Ocean. Now his corals are helping nuclear scientists understand how water circulates in our oceans.

ANSTO's Quan Hua, David Fink and other Australian scientists used annual growth rings in Darwin's corals to help them chart the circulation of the Indian Ocean over the last 200 years.

The team tested for radiocarbon, which occurs naturally as well as being produced by nuclear explosions. By comparing radiocarbon levels in corals collected over the past 50 years, the researchers have concluded that the surface waters around Cocos come from the far western Pacific via Indonesian currents – contrary to the views of some other researchers.

The radiocarbon levels for Cocos are similar to those for Watamu in Kenya, which provides important information about the upward movement of deep ocean waters in the north-western Indian Ocean. This could help to improve the models that oceanographers have developed to explain how water circulation in our oceans affects climate change.

The coral work is part of a larger ANSTO project that is using a technique called accelerator mass spectrometry to look for evidence of past global climate change in tree rings, glaciers, ocean sediments and ice cores.

"We got a real surprise when we looked for radiocarbon in corals formed since the 1950s and 60s nuclear bomb tests. The higher-than-expected results cast considerable doubt on current views about the origin of the surface waters around the Cocos Islands."

Dr David Fink, ANSTO environmental scientist

ANSTO capabilities and services

ANSTO has a broad range of specialised research capabilities, instruments and services. These help industry improve products and extend markets. Interaction in regard to ANSTO's commercial activities is facilitated by Access ANSTO.

Environmental services	Research expertise	• Nuclear tools for climate modelling • Groundwater assessment and modelling • Minerals analysis
	Specialised services	• Tritium measurement in groundwater • Fluorocarbon assessment for pipe leaks • Time dating of objects • Monitoring air quality • Minerals processing and handling
	Analytical services	• Environmental analysis • Ecological risk assessment (Aquarisk software) • Radiation level assessment in naturally occurring materials
	Key instruments for support	• Particle accelerators • Ion beam analysers • Atmospheric radioactivity spectrometers • Carbon dating facilities • Secondary ion mass spectrometry • Ore treatment and processing facilities

Materials processing and characterisation	Research expertise	• New material development (including biomaterials and nanotechnology) • Material optimisation • Ceramic wasteforms, encapsulation and controlled release
	Specialised services	• Structural integrity and 'remaining life assessment' • Materials processing • Materials characterisation • Medical orthopaedics
	Analytical services	• Materials characterisation • Materials synthesis • Creep fatigue analysis
	Key instruments for support	• Neutron beamlines • Hot and cold isostatic press • Optical spectroscopy • Small angle neutron scattering • X-ray diffraction • Neutron scattering • Infra-red thermal imaging • Ceramic powder facilities • JEOL and SEM microscopy facilities
Irradiation services	Specialised services	• Precision irradiation and validation • Silicon irradiation • Sterilisation services – medical and industrial • Medical isotope manufacturing
	Key equipment for support	• HIFAR, followed by OPAL research reactor • Gamma research irradiator facility • GammaCell irradiator

Safety and radiation services	Research expertise	• Radiation protection
	Specialised services	• Hazardous materials and radiation safety training • Radiation instrument calibration • Dosimeter manufacture and measurement • Radiation waste handling
	Key instruments for support	• Brachytherapy ion chambers • Dosimeter irradiation measurement facilities • Decontamination facility • Gamma pond
Medical research and manufacturing	Research expertise	• Radioisotope and radiopharmaceutical manufacturing • Drug assessment • Molecular medicine • Radiolabelling • Imaging • Apoptosis
	Specialised services	• Organic synthesis • Pharmacology analysis • Radiochemistry separations • Radiolabelling • Proof of concept analysis
	Key instruments for support	• Pre-clinical trial facilities • PET imaging • Radiopharmaceutical development laboratories

The Australian Nuclear Science and Technology Organisation is this country's nuclear research and development agency. We deliver market-leading products and services to public and private sector organisations in medicine, mining, aerospace, minerals, agriculture, manufacturing and the environment.

Our 850+ staff primarily conduct these activities at the ANSTO headquarters located on the outskirts of southern Sydney. This site contains the nuclear research reactor, the High Flux Australian Reactor (HIFAR), to be retired in 2007 and replaced by OPAL, the Open Pool Australian Light-water reactor. We also operate the National Medical Cyclotron, an accelerator facility at the Royal Prince Alfred Hospital in Camperdown, near central Sydney.

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Public information

ANSTO produces regular updates on its science and technology, has available a range of publications and conducts free tours of its site. For bookings, information or to be added to our database, please contact us.