Paihau—Robinson Research Institute

VICTORIA UNIVERSITY OF WELLINGTON
TE HERENGA WAKA

SUPERCONDUCTIVITY. ELECTROMAGNETICS. MATERIALS.

CAPITAL THINKING. GLOBALLY MINDED.
MAI I TE IHO KI TE PAE

Mohammad Siamaki,
PhD student

Professor Rod Badcock,
Deputy Director
and
Professor Nick Long,
Director

“The work of the Institute is more than research and engineering. We solve problems to make a difference in people’s lives. We engage constantly with industry partners and users of technology to keep the value in what we are doing front of mind. If you work with us, we’ll balance pushing technology to its limits and finding a commercially sound answer to real-world problems.”

“The quality of what we do is a source of pride. Doing the best work and doing commercially valuable work go hand in hand.”

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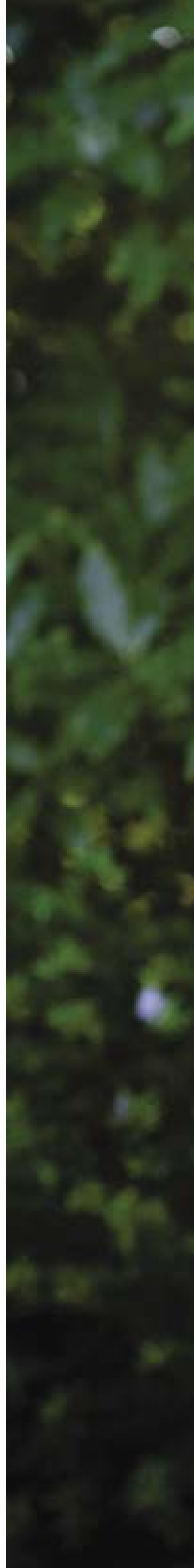


Professor Rod Badcock, Deputy Director (left) and Professor Nick Long, Director

A TEAM GREATER THAN THE SUM OF ITS PARTS

How a team of experts from multiple companies was brought together by Paihau—Robinson Research Institute to solve a problem in efficient energy distribution.

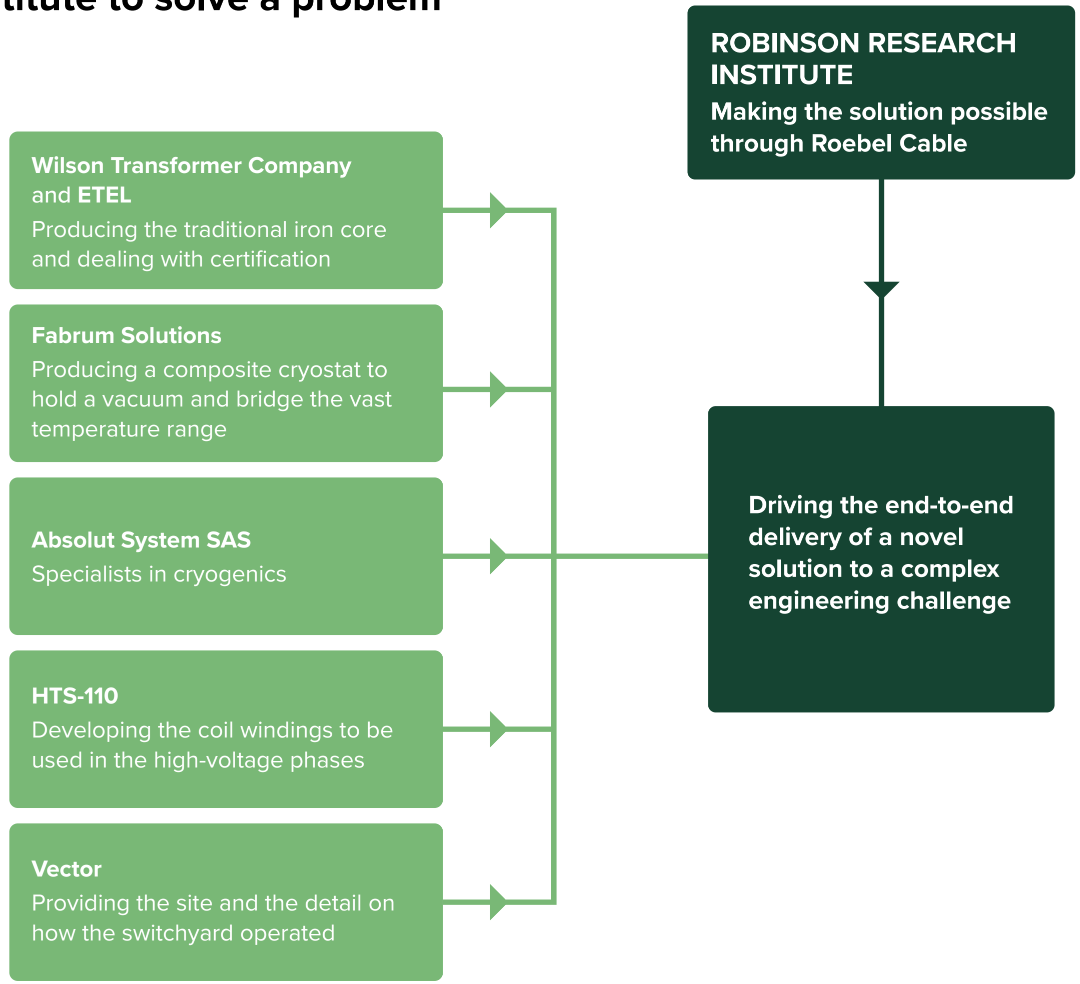
BACKGROUND

Adding a new transformer in a city location presents problems for any utility. Not only is space at a premium, but what may be basement locations are not ideal for transformers that are filled with hundreds of litres of oil. Effectively, there is a need to provide more power from the same space, while also reducing the risk of fire.

When the experts at Robinson Research Institute heard of the requirement for high power and high current density in a small space, they instantly knew the answer had to be a superconductor. The Institute had already developed the loss-preventing performance of superconductor Roebel cable for generators and motors and proposed that it would work in a transformer. To demonstrate the solution required a team who could design all aspects of the transformer, including the cryogenic systems.

WHAT WE DELIVERED

The Institute worked with a number of partners to develop a 1 MVA superconducting transformer. They demonstrated that a superconductor transformer could be more efficient than a conventional transformer at this scale. The project required a strong, multi-company team that was brought together and managed by Robinson Research Institute.



WHY IT WAS A SUCCESS

Not only does the Institute have vast experience in high-temperature superconductors, it has a track record of working successfully with commercial organisations in order to deliver the right outcomes. In this case, the Institute brought together companies from multiple locations—including internationally—that each had expertise in different areas. None had worked on an end-to-end project of this nature and had to develop specific capabilities in order to deliver the end result. The outcome was a demonstration of both the Institute's ability to tackle a project of this scale, and its excellence in project and relationship management.

And not only were the team at Robinson Research Institute proud of the outcome, they took great satisfaction from the boost it gave to two of its partners. Fabrum Solutions and Absolut System both went on to use the new capabilities they had developed to grow their businesses internationally and teamed up to form a successful joint venture called AF Cryo.

INQUISITIVE AND ENTREPRENEURIAL—ANOTHER ROBINSON PIONEER

Why the Institute is the perfect place for someone who wants to make their mark on the world.

When your ten-year-old brain wants to know how the speeds of light and electricity compare, it's a good indication that your future may lie in physics. At least, that's the experience of doctoral student, Ratu Mataira.

Wrestling with such questions also influenced—at least in part—his decision to study physics at Te Herenga Waka—Victoria University of Wellington. He recalls being impressed by answers the guide running the University open day gave to his questions; it was all the proof he needed about how seriously the campus took its physics.

A Bachelor of Science with Honours degree followed, in which Ratu majored in physics and economics, a combination that was a sign of the entrepreneurial and pioneering spirits battling inside him for supremacy.

Since then, his studies for a doctoral degree at Robinson Research Institute have opened many doors. During two overseas placements—an academic one at Cambridge University and an industrial one in Texas—Ratu has noticed that the mere mention of the work at Robinson Research Institute commands attention and a great deal of respect from anyone working in the field of superconductors. His many examples of the sheer breadth of the skills and expertise at the Institute have stunned plenty of postgraduates at other universities.

Ratu's current work at Robinson—on more advanced magnetic field sensor arrays for detecting the currents in flux pumps—has certainly helped him achieve an element of clarity about what the future holds. Like any young physicist, he knows his head is easily turned by talk of fusion reactors, but Robinson has opened his eyes to a different path—one that allows him to balance the senses of pioneer and entrepreneur inside him. That's because the Institute gives him the space and responsibility to solve problems and also has a proven track record in creating, supporting and nurturing spin-off companies. In both avenues, Ratu can see sufficient scope to really make his own individual mark on the world.

So, will he achieve what he wants to at Robinson Research Institute? It's too early to say, but perhaps a more appropriate question would be: Could he achieve what he wants to at Robinson?

And to that, the answer is a most definitive yes.

SUPERCONDUCTING

THE MACHINES OF THE FUTURE

“If we want to fly an electric 747, we need to be at a power-to-weight ratio of 23 kilowatts per kilogram. Right now, the best motors being developed can deliver a power-to-weight ratio of 16 kilowatts per kilogram. To get the kind of massive increase required, we need a new technology. The solution is superconducting electric motors.”

Professor Rod Badcock

SENDING THE WORLD OF SUPERCONDUCTOR MACHINES INTO A SPIN

We use the stability in high-temperature superconductors to develop simple, permanent magnet bearings that are contactless, allowing machines to spin without friction.

THE SCIENCE

One obstacle in the development of superconductor machines large enough to power a plane, is friction; it limits the speed at which the device can spin. Electromagnetic bearings, which use magnetic levitation (maglev) to allow the device to spin without friction, already exist but they are inherently unstable and extremely expensive.

The Institute has used its expertise to develop a simple, cost-effective approach to maglev bearings by using high-temperature superconductors. Their unique stiffness and damping properties mean maglev bearings can be constructed simply, using permanent magnets and a cold superconductor.

IMPACT AND POTENTIAL

Since 1990, air travel has increased exponentially and provided significant benefit to the global economy. Over the same period, emissions have increased by 70 percent, which is at odds with the commitments made by multiple countries under the 2015 Paris agreement.

Electrification of air—and other forms of—transport is seen as the answer. Superconductors are widely viewed as the only way to provide sufficient power at a small enough volume and weight to allow that to happen.

Freeing these large superconducting machines from the effects of friction removes one of the limitations and therefore brings electrification one step closer.

THE PEOPLE

Professor Rod Badcock is the Deputy Director of Robinson Research Institute. He is recognised as one of the leading experts in the application of HTS dynamos and cables to electric machines and, since 2006, he has been responsible for the Institute's engineering programmes that apply HTS materials into electric machines.

Rod thrives on being at the sharp end of research into high-temperature superconductivity and pushes his team and the technology to their limits.

TINY MACHINE EXCITERS DELIVERING HIGH CURRENT

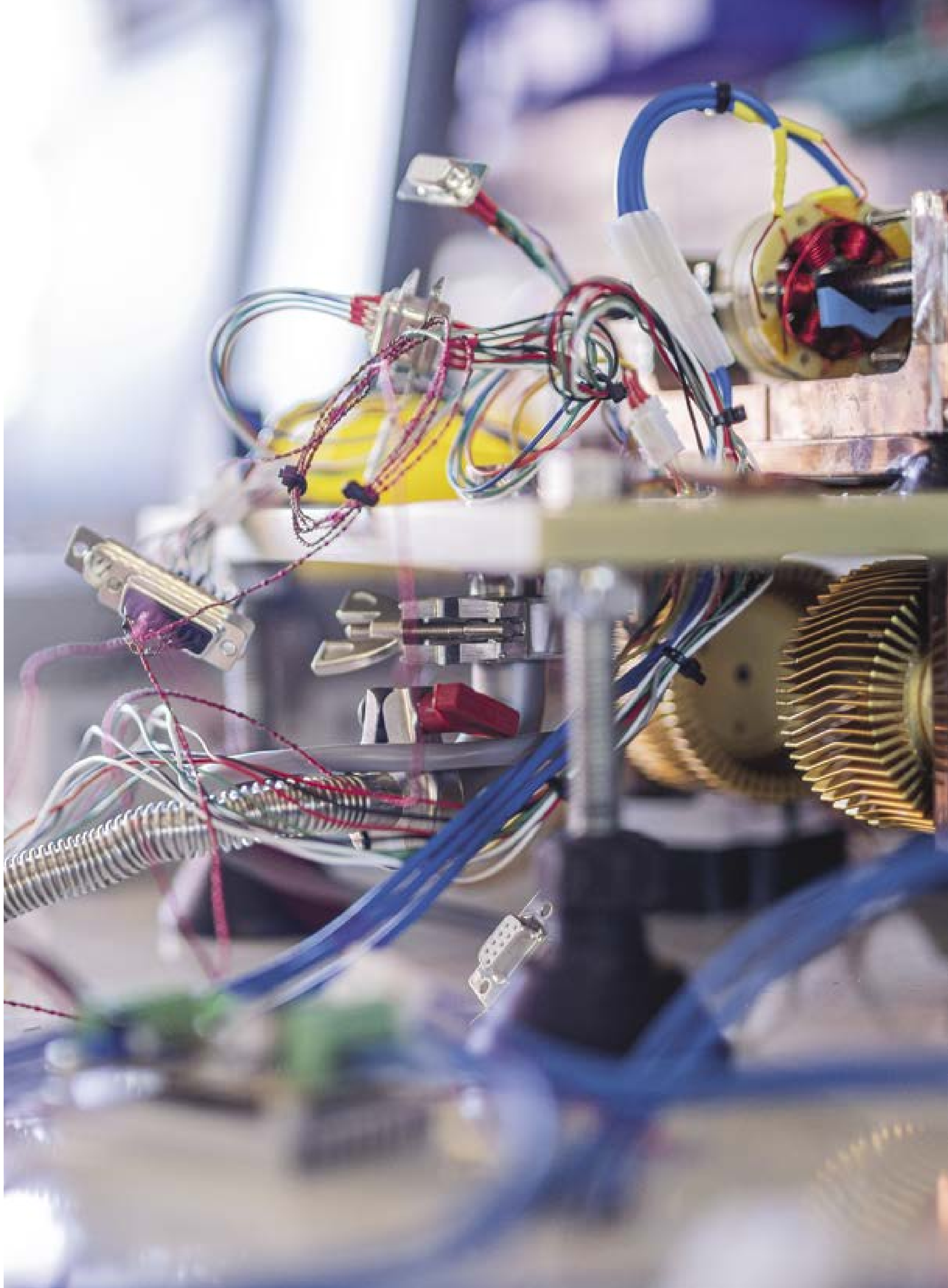
We deliver enormous electrical current from machines no bigger than a fist.

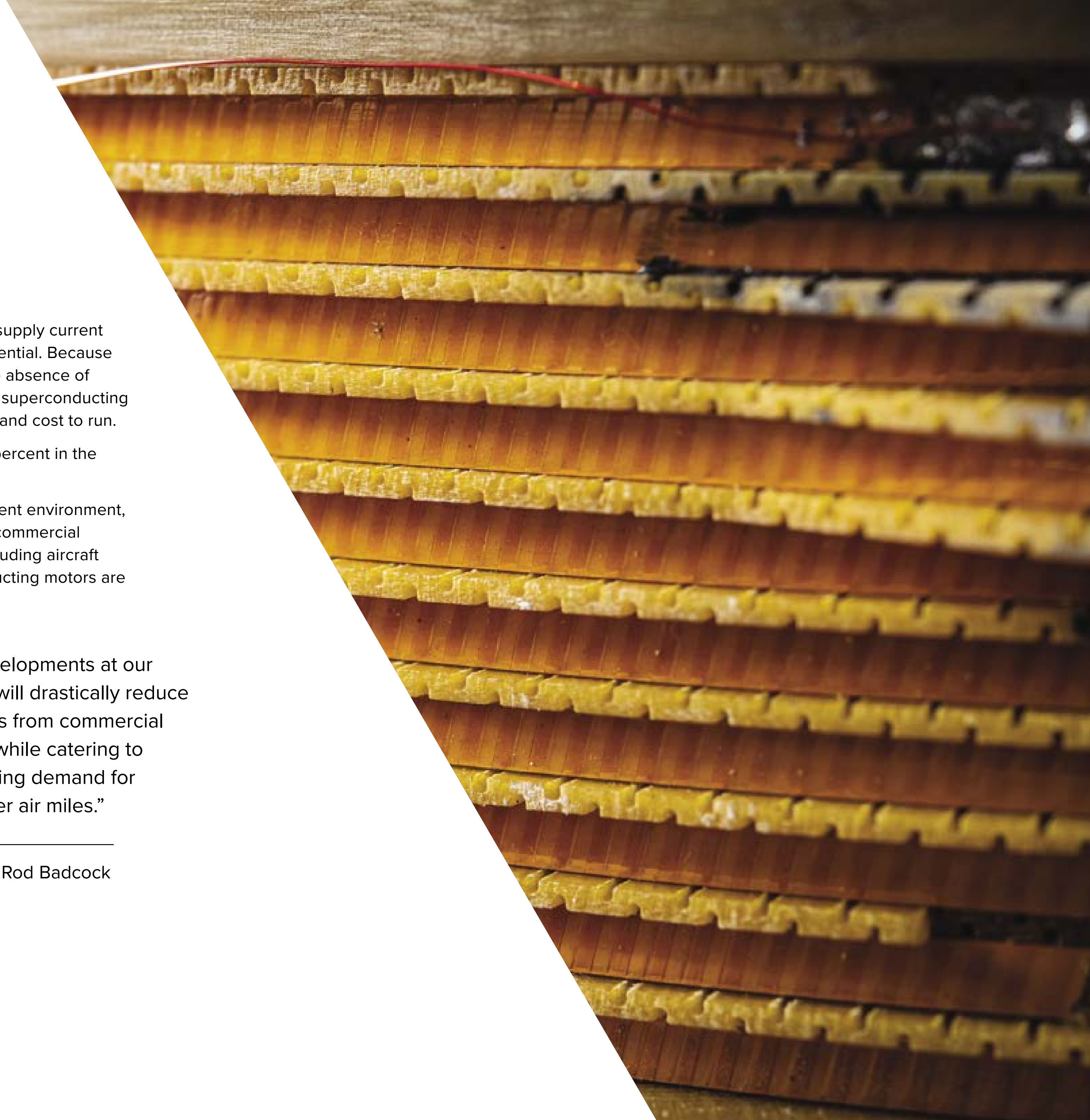
THE SCIENCE

Traditionally, current is supplied to a superconductor through copper leads. Having to run them through the casing, however, causes inefficiencies, as the cooling system has to work harder to maintain the critical temperature due to the heat generated by the resistive losses from the copper.

The Institute has developed unparalleled capability and IP in using flux pumps and superconducting dynamos as an alternative way of powering superconductors. The advantage in doing so is that there is no resistance or loss, and the magnet can therefore be run with a much smaller power supply.

A series of experimental prototypes have been demonstrated and explored, and a number of designs have achieved greater than 1800 amps.





IMPACT AND POTENTIAL

This world-first application of magnetic excitation to supply current to a high-temperature superconductor, has huge potential. Because it uses direct current, this new technique plays to the absence of resistance in the superconductor and means smaller superconducting machines can be developed that require less power and cost to run.

An additional benefit is that a reduction of up to 90 percent in the cryogenic system load can be achieved.

This is a world-class applied research and development environment, with deep technical expertise and an abundance of commercial acumen. The Institute works with global partners including aircraft manufacturers, most of whom agree that superconducting motors are the only way to build an electric airliner.

"The developments at our Institute will drastically reduce emissions from commercial aviation while catering to the growing demand for passenger air miles."

Professor Rod Badcock

PUTTING A TWIST ON TRADITIONAL SUPERCONDUCTOR TAPE

We enable large and flexible currents by repurposing a hundred-year-old technique and applying it to high-temperature superconductors.

THE SCIENCE

Superconductors have zero resistance in DC conditions, but in AC conditions, eddy currents can be created. This causes loss or heat generation which, though only small, requires additional energy to remove at cryogenic temperatures. It brings a loss of stability, reduces efficiency, and can lead to quench.

The current in a superconductor tape has a limit—usually in the hundreds of amperes. But larger machines need much higher currents—potentially thousands of amperes. Roebel cable offers a solution. It is ideally suited for coil and magnet winding and offers enhanced performance under ramping and AC operation. To make Roebel cable, wires are first cut to a serpentine shape and then planetary wound.

IMPACT AND POTENTIAL

Superconductor Roebel cable is a niche research-level product. It is the best conductor option to allow superconductors to work with high AC currents. It is most suited to transformers, generators, and motors, and is a standard option for the power industry.

Robinson Research Institute is the only place in the world with the capability to manufacture superconductor Roebel cable at large scale. To date, it has successfully proven the performance of Roebel cable in a 1 MVA distribution transformer, and the performance of the cable has also been demonstrated by CERN in a magnet prototype.

THE PEOPLE

Dr Nick Long is the director of Robinson Research Institute. The resourcefulness and enthusiasm of the diverse and world-class multidisciplinary team working at Robinson never ceases to amaze him. The development of Roebel cable manufacturing processes is one such example.

Many people thought it would be impossible to make Roebel cable in a practical manufacturable process. But with some great engineers and lots of enthusiasm, that's exactly what we managed to do."

Dr Nick Long

SUITING ALL NEEDS: MADE-TO-MEASURE MAGNETS

Our coil technology allows the customisation of superconducting magnets to meet application-specific requirements.

THE SCIENCE

Superconductor wires come in many shapes and can be wound using a number of techniques. The most appropriate combination depends on the application for which the superconductor will be used.

When it comes to cryogen-free conduction cooling, whether for a low- or high-temperature superconductor—insulated or not—the Institute has the skills, expertise, and IP to develop coils to very specific requirements.

In high-temperature superconductors, coils without insulation have been shown to protect the magnets from quench because current can jump between the turns of the coil. The no-insulation technology coils the Institute can produce are mechanically robust, have fast ramping times, and provide passive quench-management strategies.

IMPACT AND POTENTIAL

By developing coils customised to meet the requirements of each individual application, the Institute works with partners to create exactly the right superconductor coil. This may involve using existing technologies or working together to create new ones.

The coil technology sits perfectly alongside the quench-management strategies being developed within the Institute.

"Our partners come to us because we have the tools, the methods, the experience, and the people."

Konstantinos Bouloukakis

THE PEOPLE

Konstantinos Bouloukakis is an electro-mechanical engineer at Robinson Research Institute. He is responsible for the development of HTS and LTS magnet coil technology. Having the skills to develop coils in-house is a major advantage for the Institute when it comes to delivering to specific customer requirements.

PROTECTING THE INVESTMENT IN SUPERCONDUCTORS

Superconductor magnets store a lot of energy. This energy, if released in a fault, has the potential to destroy the magnet. Detecting and managing these faults, or quenches, is essential to actively protecting superconducting magnets and enabling them to survive if something goes wrong.

THE SCIENCE

In the case of a fault, areas of the superconductor can rise above the critical temperature and return to a resistive state. In high-temperature superconductor (HTS) magnets, the resistive area normally spreads very slowly, dissipating all energy in a concentrated area and leading to burn out. Building HTS magnets without electrical insulation allows current to bypass these resistive areas but may create other problems leading to destruction of the magnet.

IMPACT AND POTENTIAL

Quench detection and protection is important to ensure the magnet can handle fault conditions. Plenty of operationally critical magnets have been built in the past without much consideration placed on protection. As a result, most are no longer in operation. Active management is therefore important to protect what is a large investment and ensure safety.

OUR CAPABILITIES

- Optical fibre- and voltage-based quench detection
- Strong international network
- Quench experiments on sizeable coils with quench heaters
- Multi-physics quench simulations
- Helium-cooled and helium-free cryocooled systems
- Consultancy and expertise

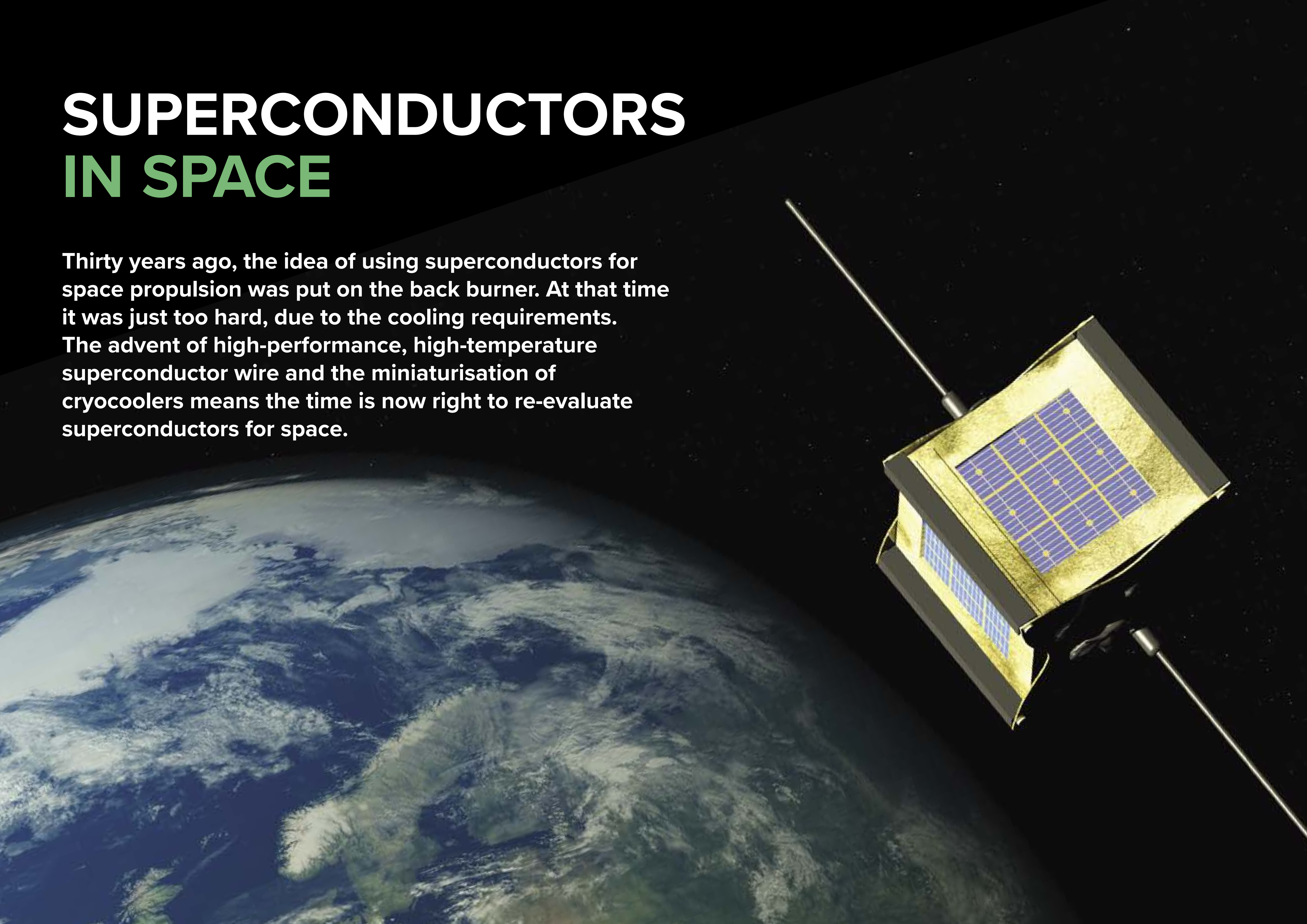
THE PEOPLE

Senior principal engineer Dr Huub Weijers (left) leads the Magnet Systems Group at the Institute. Renowned for his work in high-field magnets since 1993, he brings access to a strong international network.

Research into high-temperature superconductors is a multi-disciplinary field. From Huub's perspective, what makes Robinson Research Institute so successful is the ready access to specialists across a wide range of areas.

SUPERCONDUCTORS IN SPACE

Thirty years ago, the idea of using superconductors for space propulsion was put on the back burner. At that time it was just too hard, due to the cooling requirements. The advent of high-performance, high-temperature superconductor wire and the miniaturisation of cryocoolers means the time is now right to re-evaluate superconductors for space.



THE SCIENCE

When it comes to space machines, propulsion is one of the topics of most interest to spacecraft operators. Once in space, there is a need for manoeuvrability in order to position a satellite, change orbit, or even—if the thrust can be increased sufficiently—avoid space debris.

One means for doing this efficiently is electrical propulsion. In electric propulsion, energy is transferred to an ionised propellant, which is expelled as fast as possible. The Institute is exploring whether superconductors can provide the solution. Generating a very high magnetic field through which the ions are accelerated would increase efficiency and therefore increase thrust.

The ability to produce high magnetic fields also has the potential to be used for energy storage, radiation shielding, debris removal, and magneto-shells for atmospheric re-entry.

If energy is stored using a superconductor coil, the energy can be transferred rapidly and the system can be cycled indefinitely, without loss of performance.

"The biggest strength of the Institute is the ability to engineer solutions from great ideas."

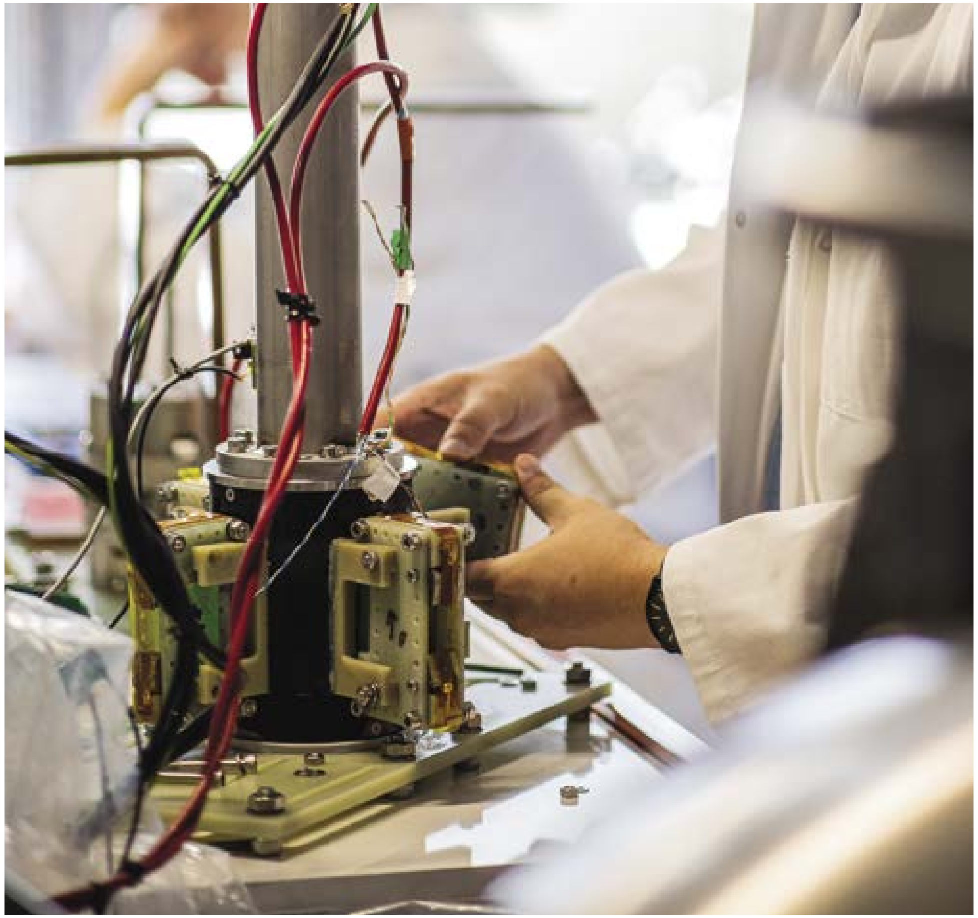
Dr Jakub Glowacki

IMPACT AND POTENTIAL

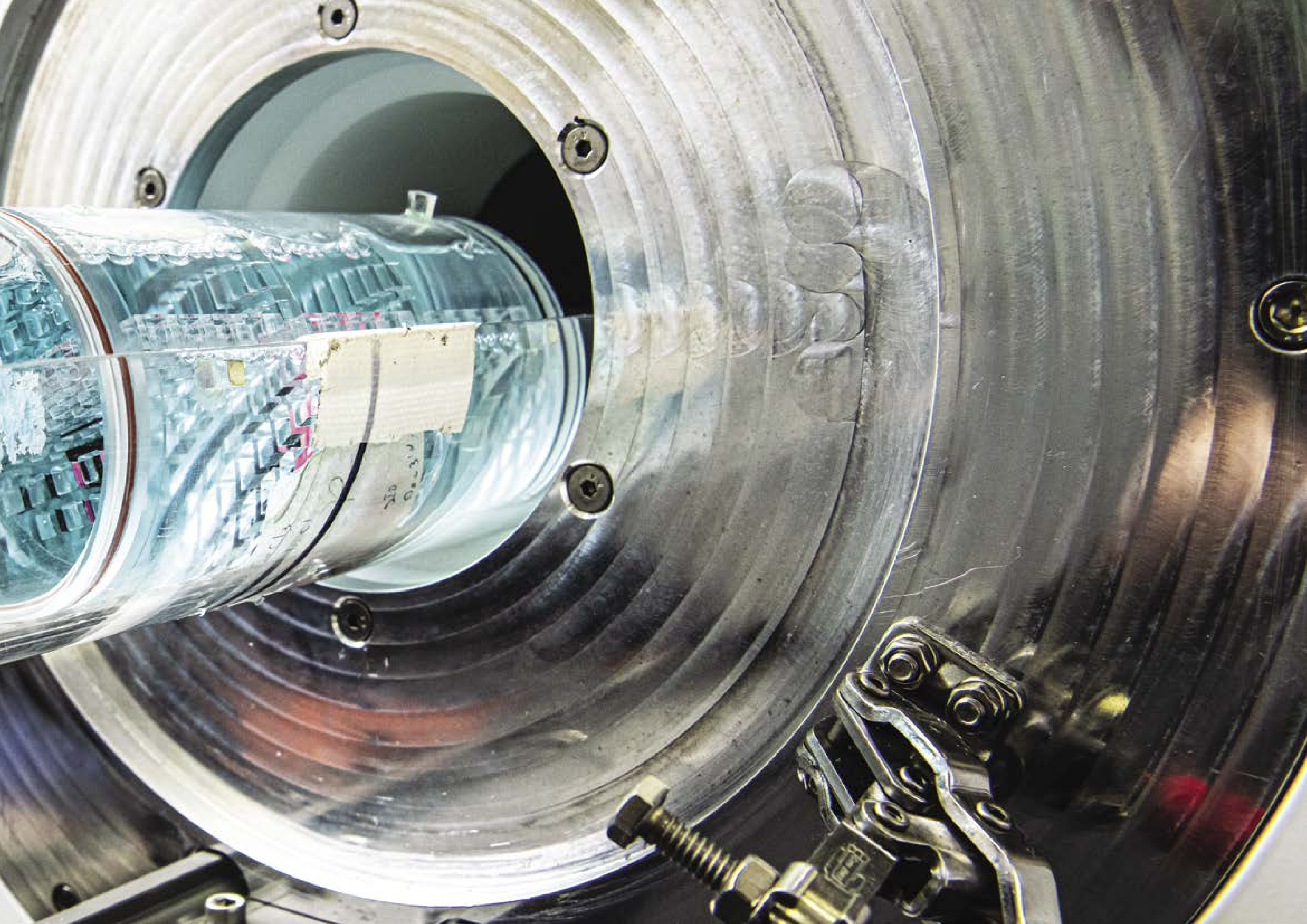
Superconductors would make machines lighter and more efficient. Electric propulsion has the potential to outperform any chemical thruster technology. It would offer an effective way of delivering a heavier payload to a desired point in space.

THE PEOPLE

Dr Jakub Glowacki is an aerospace engineer at Robinson Research Institute. For as long as he can remember, he has been inspired by the idea of building machines to go beyond what is known.

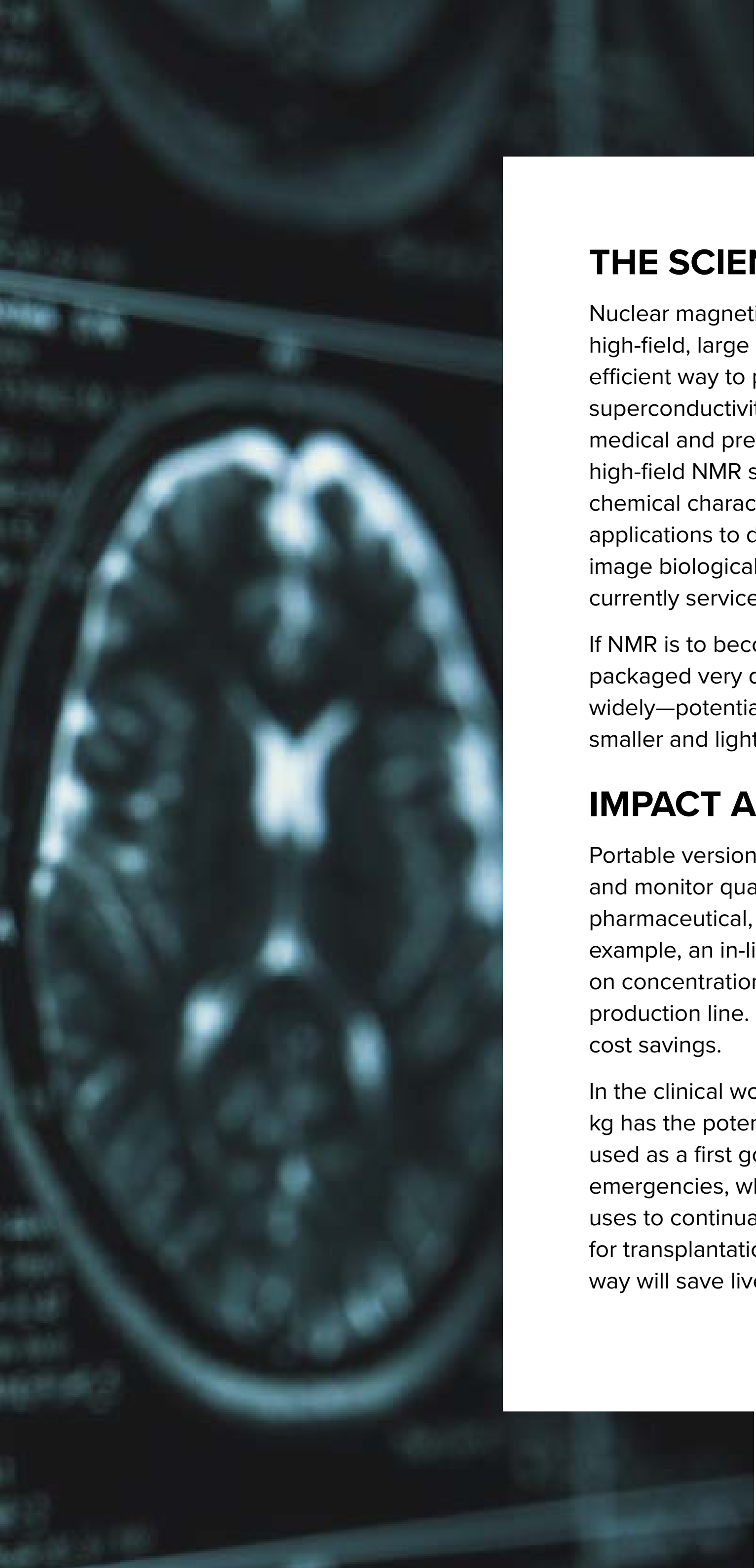


BEYOND THE CLINIC AND THE LAB



BRINGING ELITE MEDICAL SYSTEMS INTO THE MAINSTREAM

We're developing simpler, more portable nuclear magnetic resonance (NMR) and magnetic resonance imaging (MRI) technology for use in new and emerging industrial and medical applications.



THE SCIENCE

Nuclear magnetic resonance and MRI make use of high-field, large imaging volume magnets. The most efficient way to produce these fields is through using superconductivity. Commercial MRI systems are focused on medical and pre-clinical applications, and high-field NMR spectroscopy is used for specialised chemical characterisation. There are many potential applications to determine chemical structures accurately, or image biological systems using NMR and MRI, that are not currently serviced.

If NMR is to become more accessible, it needs to be packaged very differently. To be portable and used more widely—potentially in remote locations—it needs to be smaller and lighter, and have moderate power needs.

IMPACT AND POTENTIAL

Portable versions of NMR could be used to optimise and monitor quality of production across agricultural, pharmaceutical, food, and chemical industries. For example, an in-line system can provide real-time feedback on concentrations of reactants or products in a chemical production line. This would bring significant benefits and cost savings.

In the clinical world, an NMR weighing no more than 30 kg has the potential to be placed in an ambulance and used as a first go-to system for stroke diagnosis during emergencies, where speed is vital. There are also potential uses to continually monitor the condition of skin and organs for transplantation. Making NMR more accessible in this way will save lives and improve the quality of life for many.

OUR CAPABILITIES

- Design of permanent magnets for magnetic resonance
- Design and manufacture of cryogen-free superconducting magnets (LTS or HTS) for magnetic resonance and beyond
- Design and manufacture of gradient coils for MRI
- Design of transmit and receive radio frequency (RF) coils for magnetic resonance
- Specification and integration of magnetic resonance system hardware
- Development of applications for magnetic resonance systems

THE PEOPLE

Even as an undergraduate, Dr Sergei Obruchkov was inspired by the possibilities of using physics to improve human health. Now, as a senior magnet systems engineer at Robinson Research Institute, he is working with clinicians, medical scientists, experts in signal processing, material science, MR physics, and electronics to really unlock the wider benefits of NMR.

MRI FOR THE REST OF THE WORLD

Robinson Research Institute combined combined excellent engineering and science with user-centric design to develop a very compact superconducting brain-imaging magnet, accessible to much more of the world.

BACKGROUND

The Center for Magnetic Resonance Research (CMRR) at the University of Minnesota is renowned as a pioneer of MRI. The team at CMRR wanted to leverage their research into novel MRI methods to develop a new kind of MRI system that was much more accessible than existing solutions.

To do so, it needed to solve two of the biggest problems caused by traditional MRI: the size of the magnet and the infrastructure needed to support it.

WHAT WE ARE DELIVERING

The Institute has developed a very compact high-temperature superconductor magnet that has been integrated into a system designed to fully utilise the features of the compact magnet, to improve the user experience. So striking and practical was the design that it won the community choice award, as well as the Notable award in the prestigious Core77 international design awards.

HOW WE DID IT

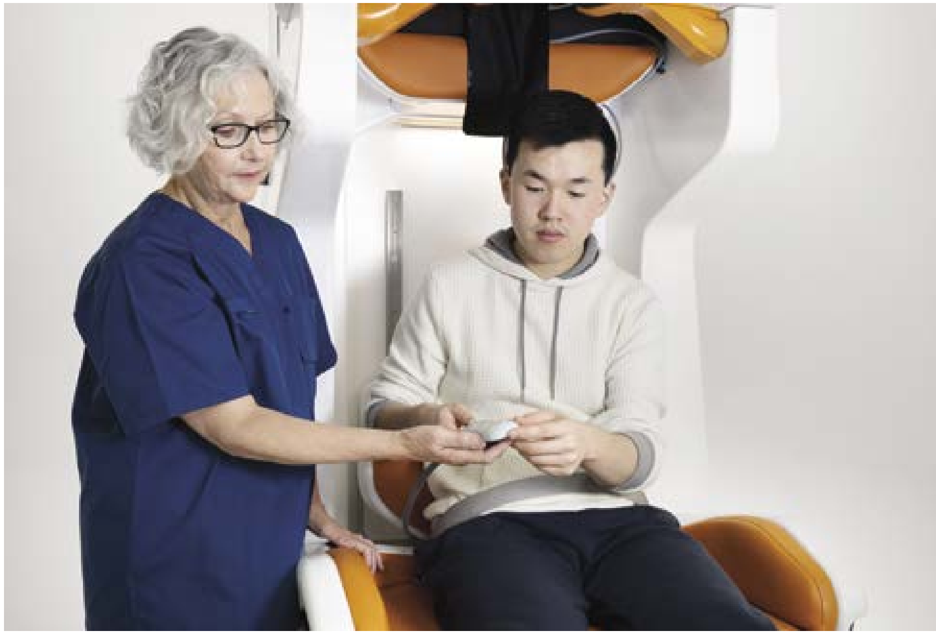
The University of Minnesota (UMN) recognised the expertise of Robinson Research Institute and started discussions about the potential for high-temperature superconductivity to meet their need. The Institute's Ben Parkinson worked through some in-principle calculations, and these helped UMN secure a five-year NIH grant to develop a high-field portable MRI device, in partnership with Robinson Research Institute.

The Institute's remit was not only to design the magnet for compatibility with their partner's MRI technologies, but also to design the solution using good practice ergonomic design to give the best possible user experience. Through its end-to-end capability in high-temperature superconductors, the Institute was able to develop a very compact brain-imaging magnet using high-temperature superconductors that can be installed easily at any site. In parallel, industrial designers from the School of Design Innovation at Te Herenga Waka—Victoria University of Wellington were embedded in the team to ensure the end product was engineered with the user experience firmly in mind.

The magnet will be integrated with our collaborators' technology at the University of Minnesota, and following the completion of clinical trials, the product will be commercialised.

GREAT MINDS IN PARTNERSHIP

- University of Minnesota
- Robinson Research Insititute
- Columbia University
- Yale University
- Harvard Medical School
- University of São Paolo



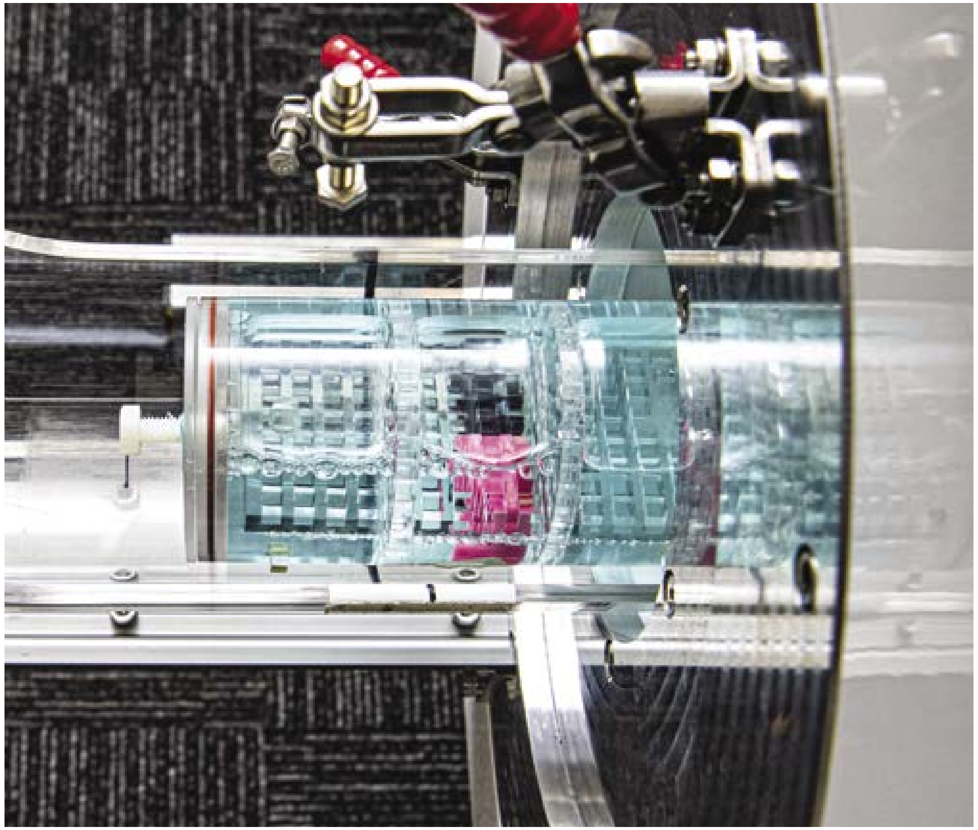
MAKING MRI MORE ACCESSIBLE

MRI is the gold standard for medical imaging. However, MRI systems can normally only be found in specialised facilities because they require specialised infrastructure. For MRI to become more widely used and universally accessible, the way these systems are built, and used, needs to change.

THE SCIENCE

MRI non-invasively images living structures by turning the nuclei of atoms into tiny radio transmitters. The MRI scanners in hospitals have been highly optimised to give the best possible images of tissue within people, and allow doctors to diagnose complicated medical conditions. The quest for best-possible imaging performance, maximum flexibility and uptime, has led to large, expensive and infrastructurally intensive systems becoming the norm.

Robinson Research Institute has the capability and expertise to build complete MRI systems. In its mission to make MRI more accessible, it is now working in collaboration with the University of Minnesota to develop a very compact brain scanner. The Institute has previously built two systems which have proved compact MRI systems can be used for scanning of human extremities such as limbs, are suitable for pre-clinical animal studies, and can be used for quality control in the food industry.



IMPACT AND POTENTIAL

Small MRI systems would make brain scans more accessible. They would bring the potential for patients to have the scan completed at a regional hub—perhaps a large doctors' surgery—rather than going to hospital.

If a compact, fit-for-purpose solution can be made—not just at the right price point—a reduced requirement for infrastructure would lead to the potential for industrial applications of MRI.

THE PEOPLE

Ben Parkinson is a senior engineer in Robinson Research Institute, and an expert in magnetic resonance systems.

"In addition to its outstanding work on superconductors, Robinson also brings the weight of the University's expertise in magnetic resonance, a legacy of the work of Sir Paul Callaghan."

Ben Parkinson

DOWN TO THE WIRE

In solving a problem for itself, Robinson Research Institute worked with a partner to create a new tool, SuperCurrent, to characterise superconductor wire.

BACKGROUND

When purchasing superconductor wire for its own internal projects, Robinson Research Institute identified that there just wasn't enough information provided by the manufacturer about the wire's performance at the operating conditions. This lack of certainty over the performance of the wire added risk to every research project. Quite simply, if the wire didn't perform as expected, a lot of research and development time could be wasted. This was a problem the Institute believed it could solve.

WHAT WE DELIVERED

The Institute developed a SuperCurrent machine to measure the current capacity of superconductor wire at a variety of temperatures and magnetic fields. What was distinctive then—and still is today—was the ability to measure the anisotropic performance: capturing the variations in performance of the wire when the magnetic fields are applied in different directions.

Since then, the Institute has made continuous improvements to the SuperCurrent machine and it now has a range of uses:

1. To inform the Institute's own projects—being able to accurately measure the performance of the superconductor wire means devices are designed to use wire efficiently
2. A publicly available database on the performance of wire has been created. System designers can use it to understand design trade-offs in how wire is used and the variations among manufacturers
3. Commercial measurement service—external clients who would like to have this data send their wire to the Institute for characterisation
4. The sale of complete instruments. The Institute will manufacture to order.

CHALLENGES

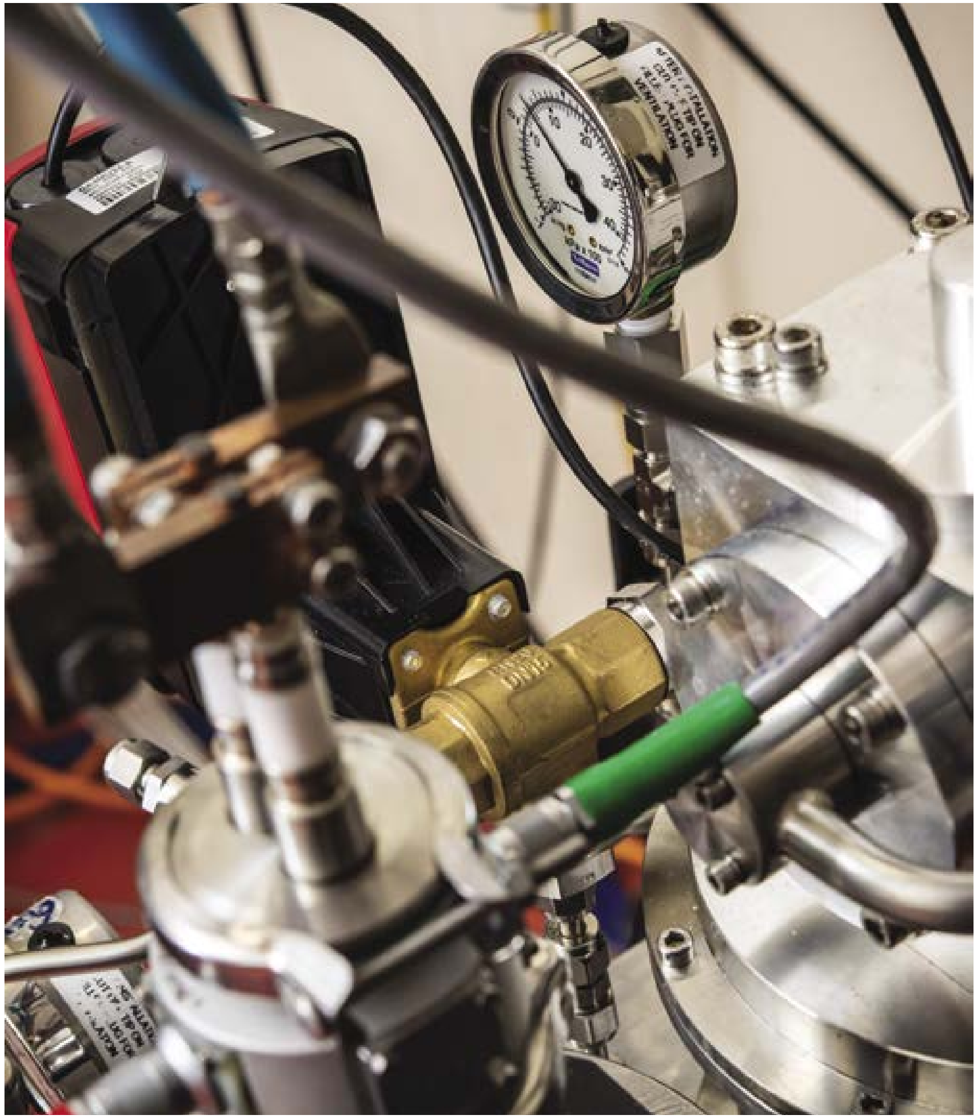
The SuperCurrent machine required a bespoke magnet. The Institute engaged HTS-110 Ltd, to design and build the highest field magnet the company had ever manufactured.

The other key challenge was to cool the sample effectively. Needing to rotate the sample when testing its anisotropic performance meant a cooling system couldn't be attached to the sample. Robinson engineers developed a new system for circulating cooling gas through a heat exchanger and the sample space.

The Institute keeps working to improve the SuperCurrent machine's capabilities. It is constantly pushing to extend the limits of temperature, magnetic field, and current.

LONG-TERM PARTNERSHIP

Robinson Research Institute and HTS-110 have been collaborating for more than a decade to push each other's capabilities forward.



SIMPLE, FAST, AND AUTOMATED TESTING OF SUPERCONDUCTOR WIRES

Checking the quality and performance of superconductor wire for both wire manufacturers and their customers—pre- and post purchase—to ensure that wire is used effectively and efficiently.

THE SCIENCE

When designing and constructing superconductor machines, it is important to know the current capacity of the wire under a variety of conditions. It must be able to support the expected current load, or the machine will not work. In addition, if wire has a large excess capacity, this may reflect an inefficient use of wire and may have implications for how quench management systems work.

The three supercurrent machines in this facility were built in-house. They measure the critical current of superconductor wires at magnetic fields up to 8 teslas, and temperatures from 77 Kelvin to 15 Kelvin. Samples can be tested across a full 360° rotation with respect to field direction. Samples are usually taken from the ends of lengths of the wire, and the length tested is about 60 mm. The total current is limited to 1500 amps. Samples may be patterned to a narrow bridge if higher current densities are required to complete a measurement.

IMPACT AND POTENTIAL

The SuperCurrent facility offers wire characterisation as a fee-for-service, for which rates are available on request. The Institute maintains a public critical-current database that helps designers identify the particular characteristics they will require.

A complete dataset across the temperature, field, and field-angle ranges may take up to 24 hours to acquire, and the density of measurements can be varied according to need. The results are returned confidentially to the contracting organisation.

In addition, the Institute builds, installs, and services SuperCurrent machines to order, and is able to customise them by negotiation.

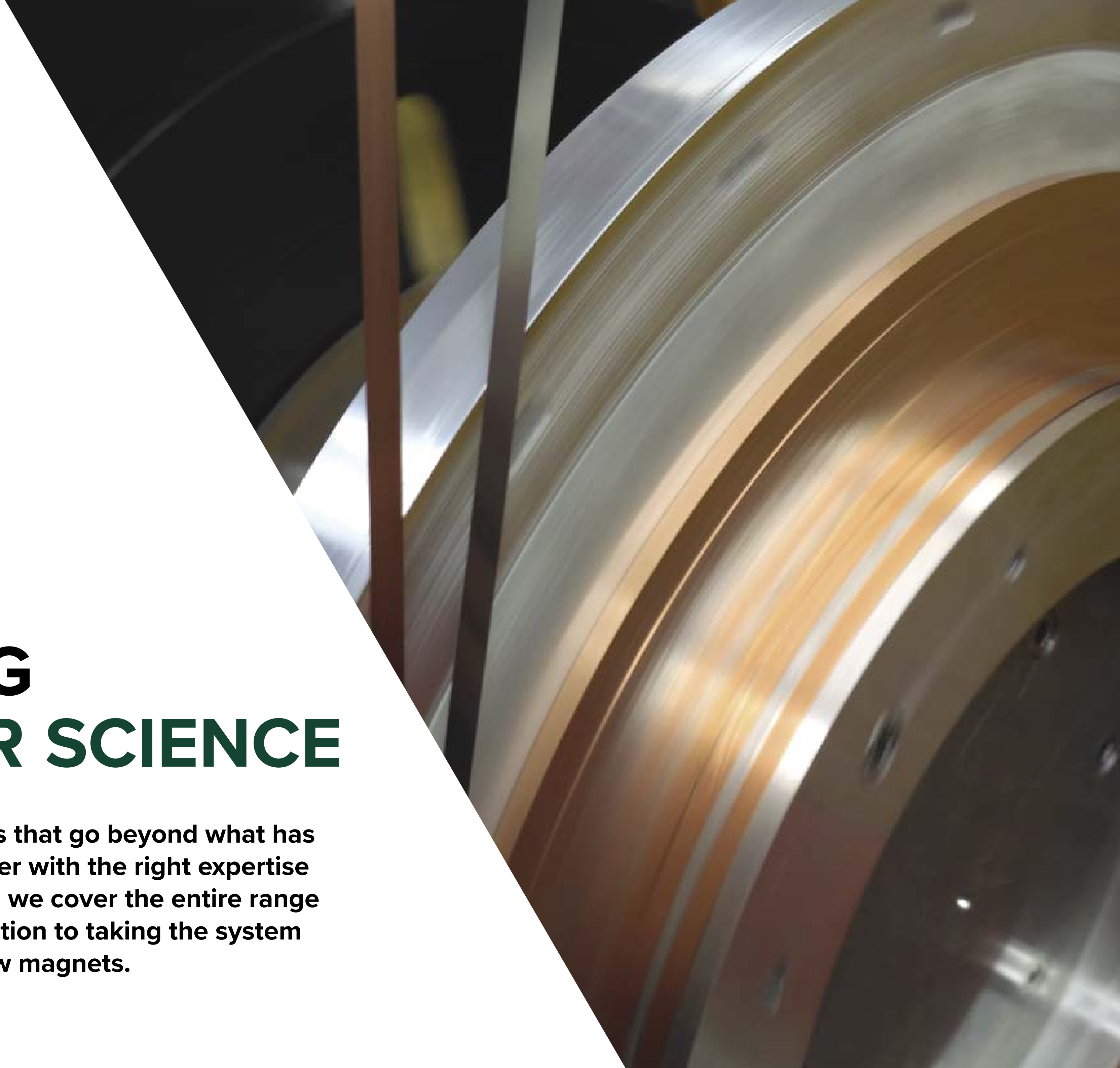
Time at the facility can also be booked by visiting academics or businesses.

THE PEOPLE

Dr Olly Pantoja manages the SuperCurrent system facility at the Institute. In his view, the facility's success is linked to the quality of data it provides. He enjoys working with staff, students, visiting academics and manufacturers.

"Our datasets assure project leaders they have the right superconductor wire for their application."

Dr Olly Pantoja



ENABLING FRONTIER SCIENCE

When developing magnets that go beyond what has been done before, a partner with the right expertise is invaluable. At Robinson, we cover the entire range from material characterisation to taking the system view when developing new magnets.

THE SCIENCE

There is large demand for high-field magnets worldwide, with applications ranging from forefront studies in quantum mechanics to use in nuclear fusion and magnetic resonance magnets.

To begin with, the Institute has a broad capability in the characterisation of superconducting materials. Our coil technology portfolio includes HTS and LTS windings—using insulated conductor or with engineered resistivity between turns—and high-current cables. The Institute has a track record of engineering and building complete superconductor systems that work. These are exactly the skills and expertise that are required to overcome the challenges in the development of high-field magnets.

IMPACT AND POTENTIAL

Robinson Research Institute's core mission is to develop technology with our partners and commercialise it. It is an unusual approach, especially when applied to high-field magnets. Other institutes across the world have experience in developing such magnets, but they are focused on their own goals to create new science or chase records in magnetic fields. As such, there is little downtime for these resources to be used by external researchers or companies.

The Institute's aim is to provide support to researchers and partners to help overcome some of the challenges associated with high-field magnets and find successful ways to apply them in the real world.

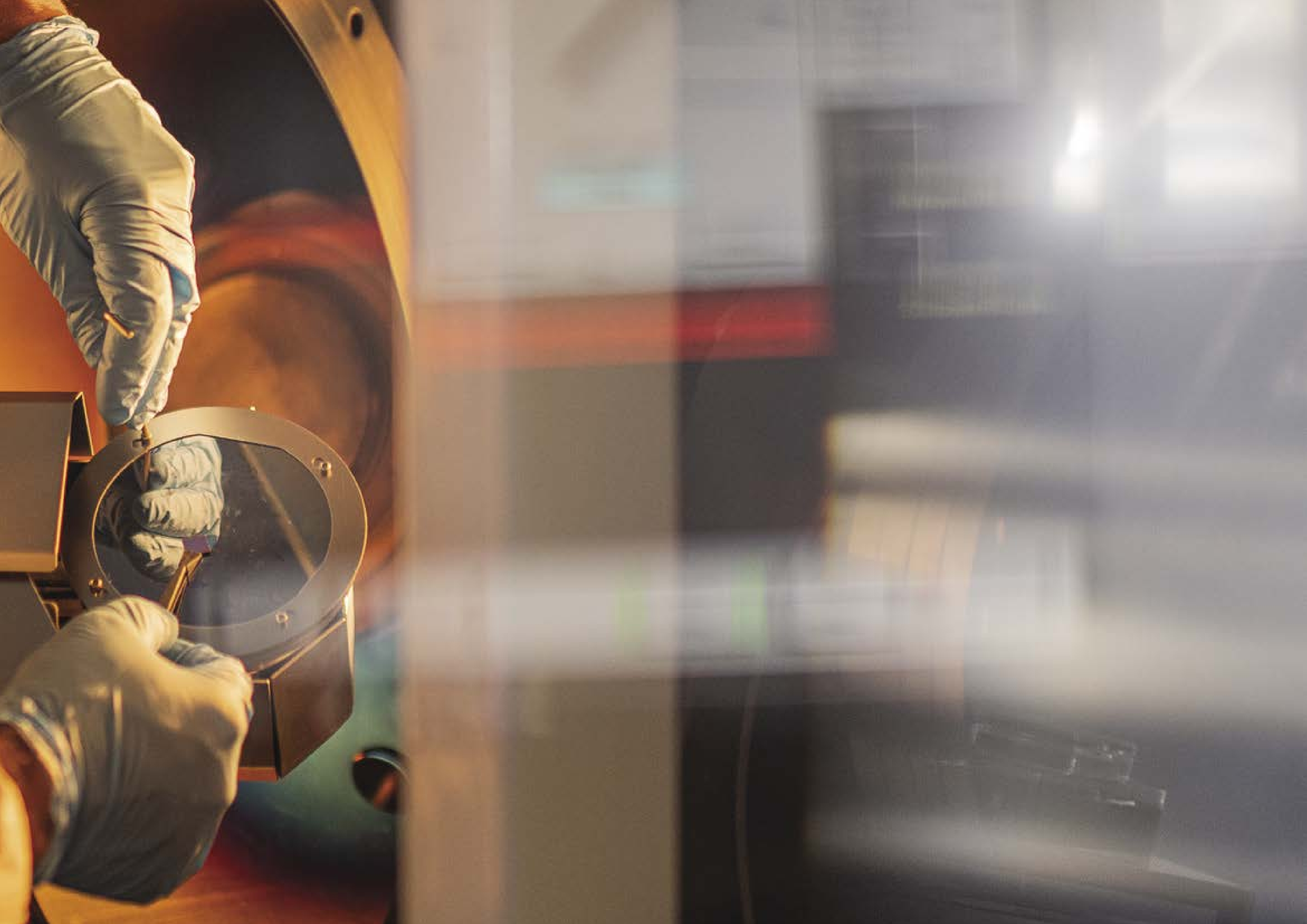
THE PEOPLE

Senior principal engineer Dr Huub Weijers leads the Magnet Systems Group at the Institute. For ten years, he was the project leader on the NHMFL 32 tesla all-superconducting magnet, the first in the world to exceed 30 teslas.

"To fully understand a magnet, you need to understand all the materials that go into the magnet and how the magnet fits into the larger system."

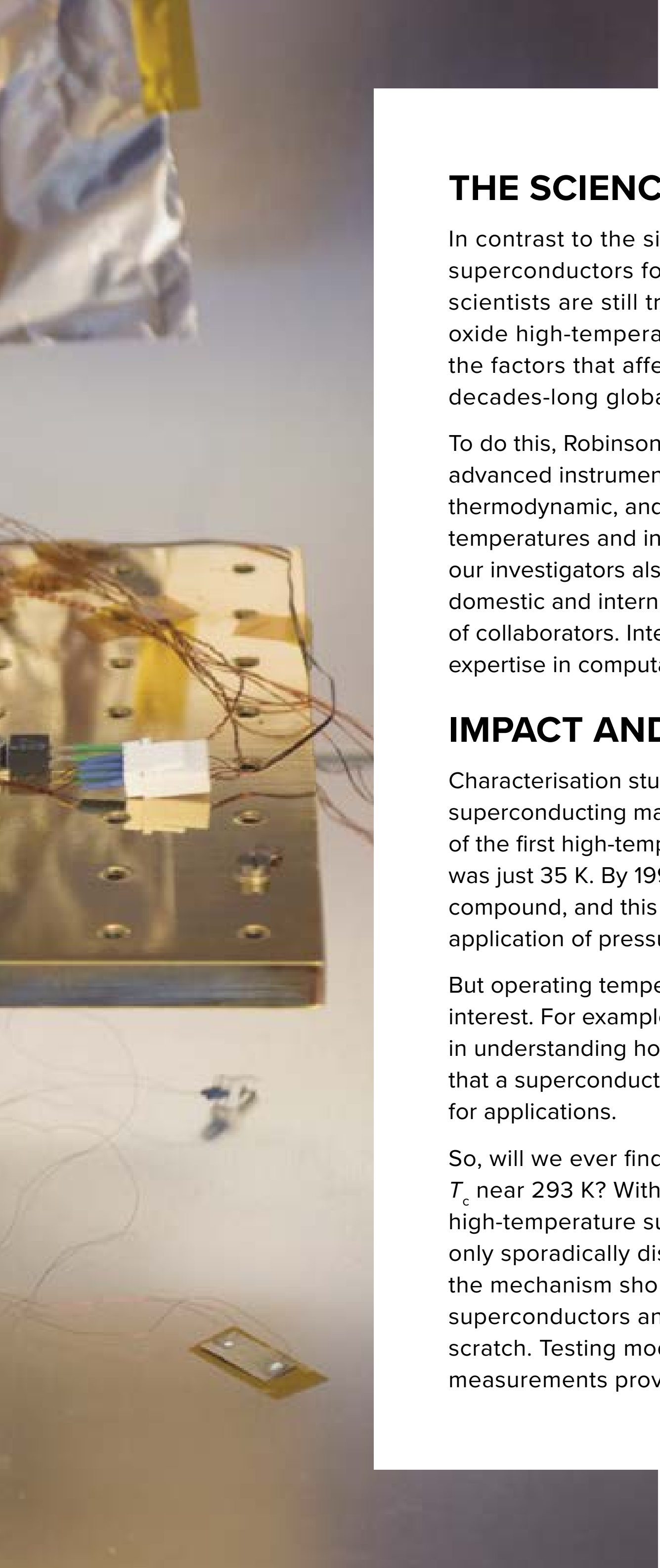
Dr Huub Weijers

MAKING A MATERIAL DIFFERENCE



THE JOURNEY TOWARDS ROOM-TEMPERATURE SUPERCONDUCTORS

Although all superconductors can transport electricity without loss, how well they do so varies from one material to the next. Superconductivity depends on intrinsic properties of a material, such as crystal structure, defects, and dopant atoms, as well as external conditions like temperature, pressure, and magnetic field. Characterising the influence of these factors helps to advance our understanding of what makes a material a superconductor and may one day lead to the development of room-temperature superconductors.



THE SCIENCE

In contrast to the simple metallic low-temperature superconductors for which a Nobel-prize-winning theory exists, scientists are still trying to understand the physics of the complex oxide high-temperature superconductors. Fundamental studies of the factors that affect superconductivity are key to this decades-long global effort.

To do this, Robinson Research Institute hosts a suite of advanced instruments capable of performing various transport, thermodynamic, and optical measurements down to very low temperatures and in high magnetic fields and pressures. In addition, our investigators also have access to a wide range of other domestic and international facilities through an extensive network of collaborators. Interpretation of data is supported by in-house expertise in computational modelling and analysis.

IMPACT AND POTENTIAL

Characterisation studies are essential for optimising new classes of superconducting materials. The maximum operating temperature (T_c) of the first high-temperature superconductor discovered in 1986 was just 35 K. By 1993 T_c had increased to 133 K in a related compound, and this could be boosted further to 160 K by the application of pressure.

But operating temperature is just one of many parameters of interest. For example, we have made many important contributions in understanding how to maximise the amount of electric current that a superconductor can carry, which is arguably more important for applications.

So, will we ever find a room-temperature superconductor with a T_c near 293 K? Without knowledge of the mechanism behind high-temperature superconductivity, new materials are only sporadically discovered by trial and error. Identifying the mechanism should help us narrow the search for new superconductors and might even allow us to design one from scratch. Testing models against data from characterisation measurements provides a path towards that goal.

CAPABILITIES

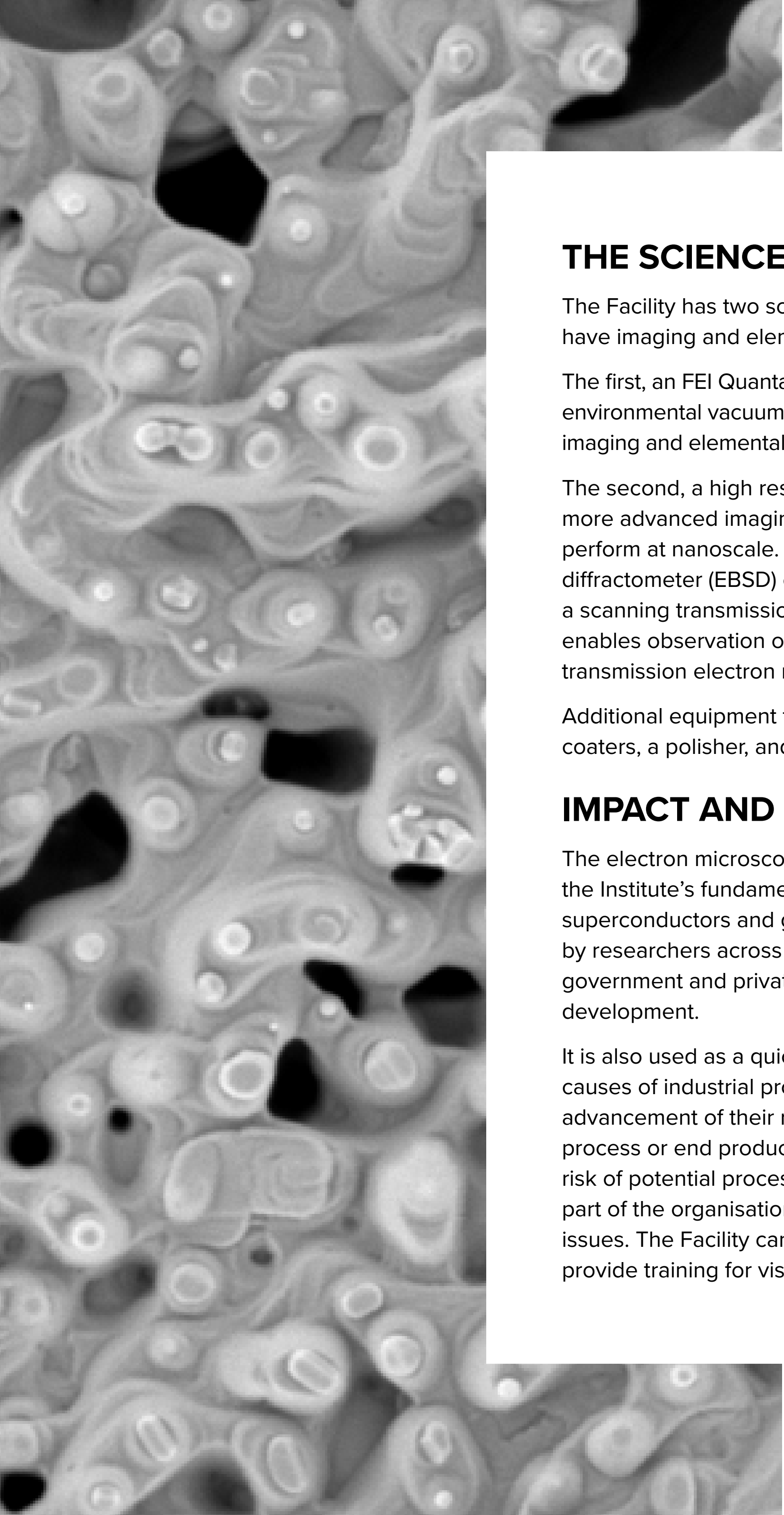
- Superconducting quantum interference device (Squid)—an extremely sensitive magnetometer
- Physical properties measurement. Thermal conductivity, resistance, specific heat. Capability to measure down to -270°C and in high magnetic fields—up to 9 teslas
- Strong capability in computational modelling

THE PEOPLE

Dr James Storey specialises in the physics of high-temperature superconductors, with a focus on computational modelling of their distinctive electronic properties. He has strong links with Cambridge University and thrives on the stimulating environment that is Robinson Research Institute.

FACILITATING GREATER UNDERSTANDING OF MATERIALS

We use electron microscopes to conduct research into the structure and composition of materials to support academic research and commercial activity.



THE SCIENCE

The Facility has two scanning electron microscopes, both of which have imaging and elemental analysis capabilities.

The first, an FEI Quanta 450 SEM, can operate in high, low, and environmental vacuum modes. It is robust and used for basic imaging and elemental analysis, including elemental maps.

The second, a high resolution FEI Nova NanoSEM 450, has more advanced imaging and analytical features that enable it to perform at nanoscale. The addition of an electron backscatter diffractometer (EBSD) enables crystal orientation mapping, while a scanning transmission electron microscope detector (STEM) enables observation of samples that typically require access to a transmission electron microscope.

Additional equipment to assist in sample preparation include metal coaters, a polisher, and a precision ion polishing system.

IMPACT AND POTENTIAL

The electron microscopes are an essential tool for advancing the Institute's fundamental research into high-temperature superconductors and green metallurgy. The Facility is also used by researchers across the University campus and available to government and private organisations for their research and development.

It is also used as a quick diagnostic tool to identify contaminants or causes of industrial processing failures. Use of the SEMs enables advancement of their research by optimising a developmental process or end product. As a diagnostic tool, it helps reduce the risk of potential processing issues going unnoticed, and forms part of the organisations' mitigation strategies to pre-empt safety issues. The Facility can either process samples and report back or provide training for visitors to do the work themselves.

THE PEOPLE

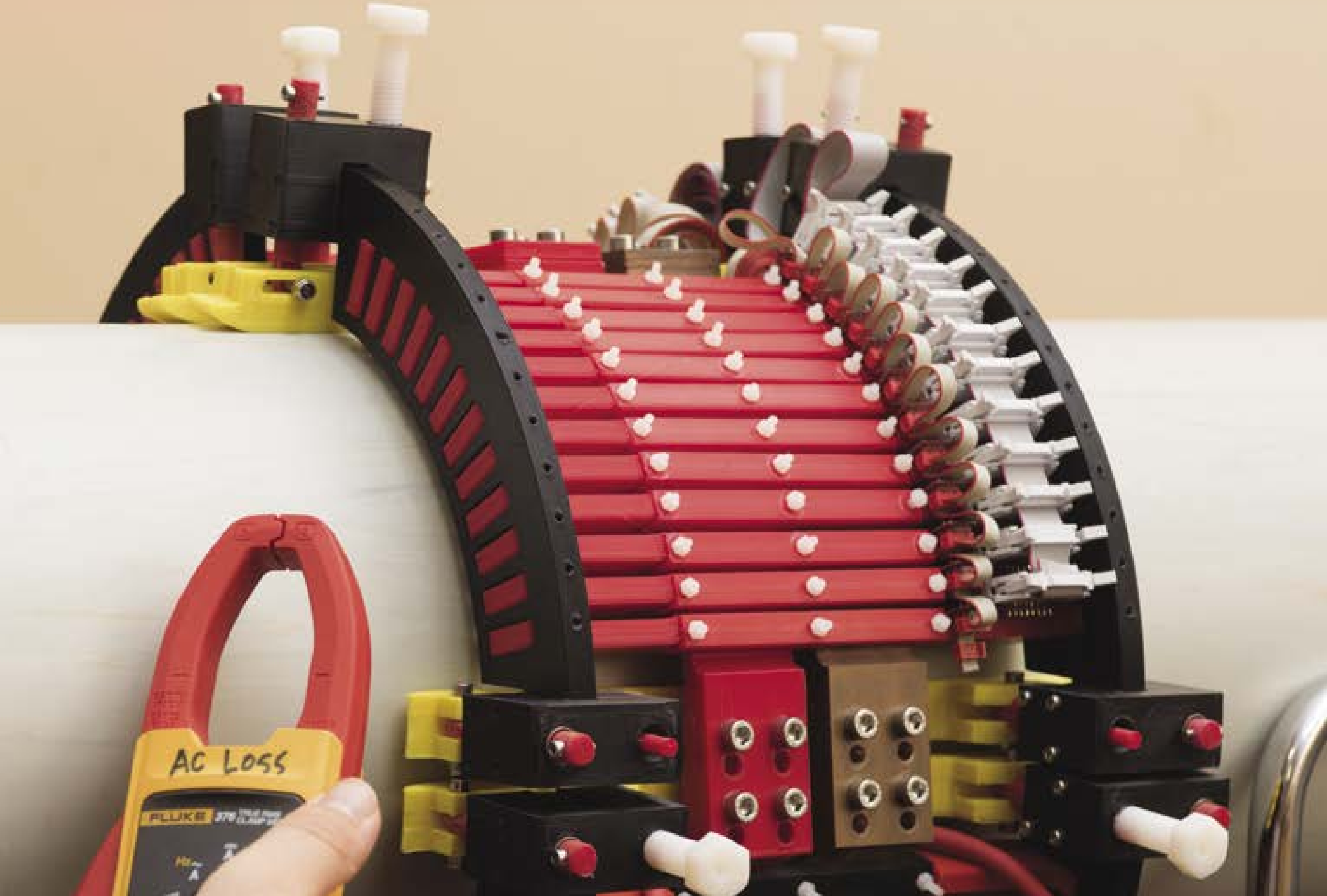
Sarah Spencer has more than 15 years' experience in electron microscopy and runs the scanning electron microscope suite at Robinson Research Institute.

"Microscopy facilitates everything from PhD research and publications to solving industry problems."

Sarah Spencer

USING MAGNETIC FIELDS TO PREDICT FAULTS AND IDENTIFY CORROSION

Induced currents in encased steel or operational currents in powerlines produce magnetic fields which can be interrogated to detect defects and faults.



THE SCIENCE

We develop and use magneto-resistive sensors to measure the magnetic field; either those induced by an eddy current, or those occurring around electrical conductors (in the case of powerlines). The magnetic signatures are then interpreted via a set of data analytics algorithms designed to identify the data patterns.

In the case of powerlines, the pattern recognition system has been built using machine learning to look at fluctuating magnetic fields due to changes in currents, and recognise anomalies.

Current work also extends to using sensors and artificial intelligence-based control to mitigate potential hazards and ensure the safety of autonomous robots in rugged outdoor environments.

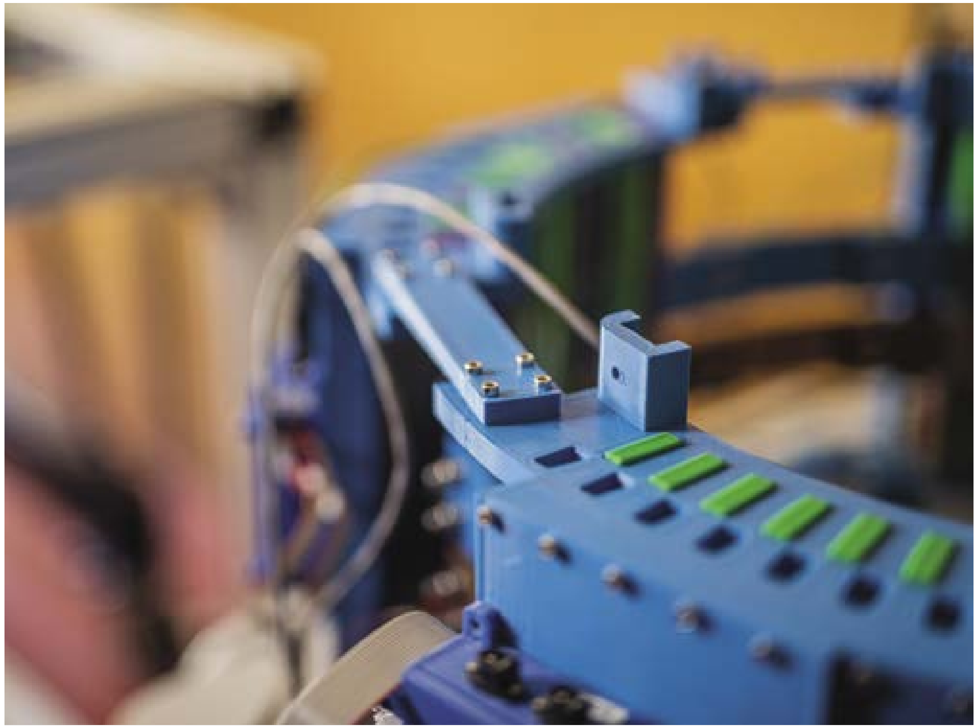
IMPACT AND POTENTIAL

Whether it is used in pipes or to reinforce concrete columns—such as in buildings, bridges, and power poles—steel eventually corrodes. Where that steel is underneath other material, it cannot be inspected by eye. A non-destructive testing tool has been developed to identify changes in steel thickness and allow the asset owners to target maintenance effectively. This saves maintenance costs and prolongs the life of assets; accurate assessment and timely maintenance can also prevent catastrophic failure occurring.

In the case of electricity distribution, a low-cost, widely distributed monitoring solution has been developed to monitor current levels in powerlines. It allows asset owners to identify when and where faults are occurring, avoiding lengthy outages and unnecessary repairs, and target only those pieces of equipment that are showing signs of a fault.

CAPABILITIES

- Expertise in developing sensing hardware
- Creation of sensor data interpretation algorithms
- Using artificial intelligence and machine learning in sensing and control systems
- Experience with advanced process control
- Knowledge and expertise in magnetic fields and their interpretation

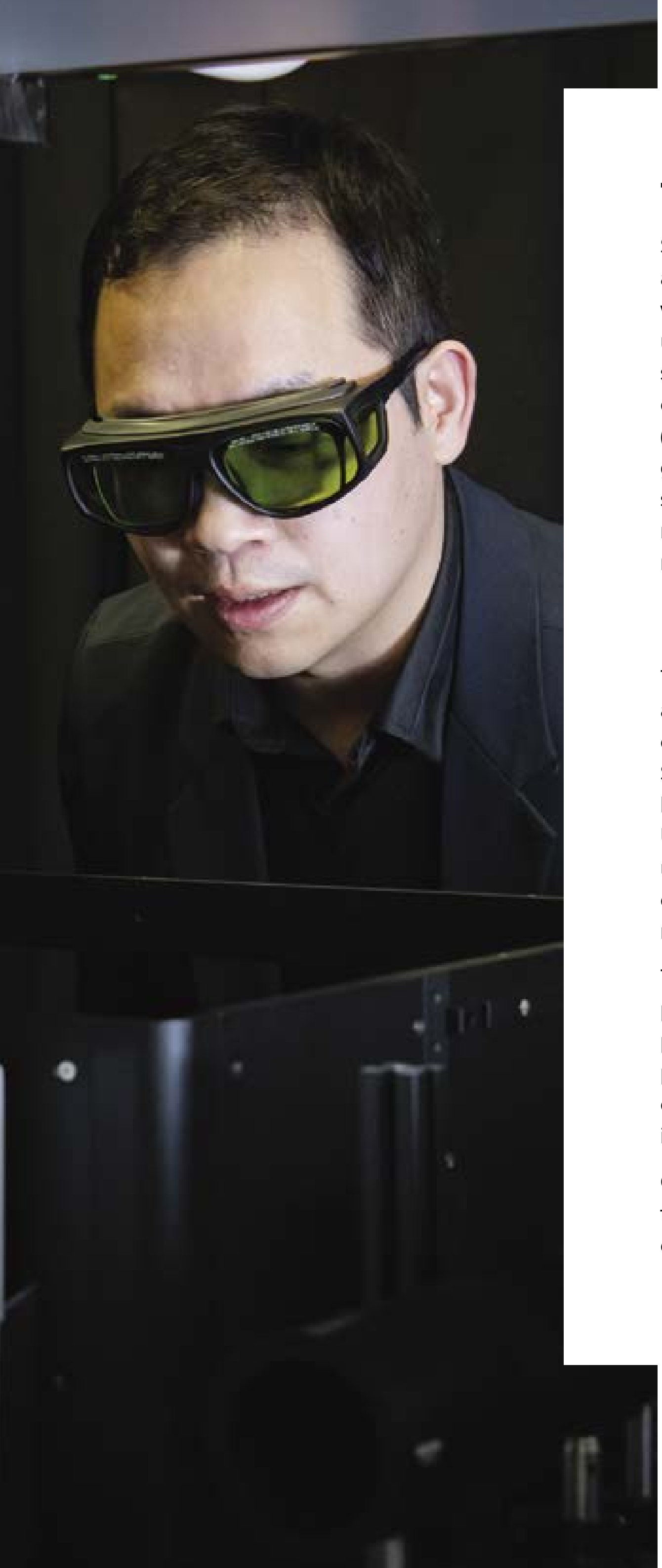


THE PEOPLE

Principal engineer Dr Fiona Stevens McFadden likes to work in applied research and find solutions to real-world problems.

DEVELOPING AND INVENTING NEW ULTRAFAST SPECTROSCOPY TECHNIQUES AND EQUIPMENT

We design and use state-of-the-art ultrafast laser technology for fundamental research and advanced material characterisation.



THE SCIENCE

Spectroscopy is all about the reaction of materials to light and measures how light is changed during an interaction with a material sample. Using spectroscopy, we can understand the properties of the material, whether a semiconductor for a printed solar cell, a photonic chip, or a fluorescently tagged protein. Ultrafast spectroscopy (UFS) is an increasingly popular technique that provides greater depth of insight compared with traditional optical spectroscopy. It uses ultrafast pulsed lasers to measure material dynamics that occur in very short timescales at molecular level.

IMPACT AND POTENTIAL

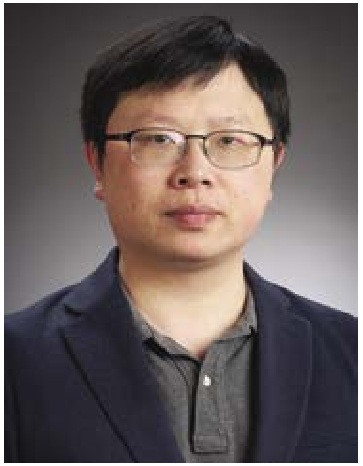
The patented techniques and equipment developed and used in Robinson Research Institute—in collaboration with the School of Chemical and Physical Sciences—includes access to advanced ultrafast light sources. We have developed turnkey integrated UFS solutions. This enables analysis across the ultraviolet-visible-near-infrared spectrum within a single experiment, and the ability to integrate multiple UFS methods into a single product solution.

This capability is ideal for studying how samples progress through intermediate states as they photosynthesise and will therefore have a large role to play in the commercial development of organic solar cells to replace silicon, with the potential to integrate into existing industrial workflows.

Our partnerships with laser manufacturers also give the Institute access to light sources that are not yet commercially available.

CAPABILITIES

- Access to spectroscopic laboratories with advanced femtosecond laser sources
- High pulse energy and high average power ultrafast lasers
- Access to advanced light sources that are not yet commercially available
- Patented techniques and equipment
- Strong collaboration with other innovators in laser techniques and material sciences



THE PEOPLE

Dr Kai Chen manages the ultrafast spectroscopy lab located at the School of Chemical and Physical Sciences (SCPS), Te Herenga Waka—Victoria University of Wellington. He has a background in physics, and most of his research is in the properties of materials. During his career, he has developed and implemented new and experimental techniques that were inspired by crucial physics processes and questions.

PRODUCING MAGNETIC COMPOSITES WITH UNIQUE PROPERTIES

We develop compounds to interact in functional ways with magnetic fields. This has, for example, resulted in the capability to effectively guide magnetic fields for inductive power transfer and magnetic field sensing.

THE SCIENCE

Mixing different soft magnetic compounds with organic or polymer resin to make them more flexible and formable. The Institute is working with its partners at GNS Science and the University of Auckland to develop flux-guiding materials that have high permeability and will also withstand impact. The use of natural magnetic materials and magnetic nanoparticles in our research is what makes it stand out.

We can also exploit the magnetic anisotropy found in most magnetic materials through thin film fabrication and alignment of magnetic nanofibres to enhance their flux-guiding properties.

IMPACT AND POTENTIAL

Being able to withstand impact and guide magnetic flux is of practical importance in the development of charging pads for electric vehicles. With our partners we are developing in-road pads that can charge vehicles moving on motorways. These materials are also of use in pads for static electric-vehicle charging.

THE PEOPLE

Senior scientist Dr Shen Chong has published work on both superconductivity and magnetism. He has expertise in the characterisation of functional properties of nanomaterials, as well as conducting magnetic sensor validation studies.

CAPABILITIES

- Expertise in characterising the functional properties of nanoparticles
- Furnaces that can reach as high as 1700°C and mixed reactant gases
- Hydraulic presses and moulds to prepare soft magnetic composites
- A high-pressure probe for optical and resistivity measurements at cryogenic temperatures
- Materials mechanical testing facilities (Tinius Olsen H10KT)
- Training and consultation

GROWING QUALITY SAMPLES FOR RESEARCH

Heating substances to high temperatures and then cooling them to create single crystals is integral to the reliable study of the structural, magnetic, and electronic properties of materials.

THE SCIENCE

Materials are heated to very high temperatures using a self or additive flux to help melt the reactants. These are then cooled at a set rate to allow single crystals to form.

Thin film samples of a few atomic layers thick have electrical properties different from bulk materials. For example, we have made low dimensional layered organic-inorganic semiconductors that showed ferromagnetism at low temperatures. We have also prepared and investigated several families of iron-based superconductors that could operate at much higher magnetic fields compared to the LTS. These new superconductors could potentially replace LTS-based magnets currently used in MRI and NMR for higher image and signal resolution. We have facilities to produce these using pulsed-laser deposition or sputtering.

IMPACT AND POTENTIAL

The Institute is finding methods to grow quality samples of single crystals to help researchers probe the intrinsic properties of materials without the adverse effects introduced by impurities. Single crystal samples allow researchers to study both the original material and the pure crystal to make comparisons, draw conclusions and characterise the material effectively. These samples are ideal to be studied under extreme environments where we have high-pressure probes to explore their magnetic, electronic, and optical properties up to several GPa.

Access to the facility allows research and commercial partners to investigate and prototype new compounds.

THE PEOPLE

Dr Shen Chong enjoys the study of new materials and thrives on the collaboration with colleagues from multiple disciplines. He prides himself on the production of quality samples to aid in the advancement of research, and his facility is in high demand from those in the Institute and beyond.

CAPABILITIES

- Pulsed-laser deposition (to come) to prepare low dimensional functional materials
- Expertise in characterising the functional properties of nanoparticles
- Furnaces that can reach as high as 1700°C
- Vertical furnaces that can quench the reaction
- High magnetic field and low-temperature magnetic and physical properties measurement systems
- Training and consultation

“We have the capability to produce high quality polycrystalline and single crystal samples, enabling great science to be undertaken.”

Dr Shen Chong

Image: *John Morris Group*

PUTTING MAGNETIC MATERIALS INTO NEW ELECTRONIC DEVICES

We use the natural magnetism of electrons—known as 'spin'—to make electronic devices from magnetic materials that are more sensitive, energy efficient, and powerful than today's devices.

THE SCIENCE

There are plenty of large global manufacturers commercialising spintronics (spin electronics) devices and concepts. An example application is data storage, where spintronics technology allowed the storage capacity of magnetic hard disk drives to grow by a factor of 10,000x in 20 years. Now, the second generation of spintronic computing devices is being developed. They do not rely on spinning magnetic discs and a single reader to decipher information. Instead they replace the spinning disc with a large array of billions of magnetic memory elements that can be addressed via metal interconnects. They have no moving parts and can be scaled down to provide high density storage, with high energy efficiency, in a very small package.

IMPACT AND POTENTIAL

At the Institute, rather than compete in the manufacture of these tiny devices, we study the basic physics of new magnetic materials and spintronic device concepts, assisting with the effort to make the existing technology more effective or efficient, find new applications in sensing, and harvest energy to power electronics to create energy-efficient computing. Computing technology always advances quickly, and revolutionary new architectures such as superconducting, neuromorphic, and quantum computing will bring enormous benefits to businesses and communities worldwide. The Institute's excellent spintronics and magnetic materials research provides a direct link to the global research leaders developing the new computing and electronic devices that we will all be using in the future.

THE PEOPLE

As an experimental materials research physicist and a senior scientist at Robinson Research Institute, Dr Simon Granville's research background in thin film magnetic materials took him to Switzerland and back, leading to his extensive network of active spintronics research partnerships across Asia, Australia, Europe, and North America. He is recognised as a regional authority on magnetic materials and spintronics research, with an enthusiasm for developing cross-disciplinary R&D projects.

"Much of the understanding of fundamental superconductor physics that has been acquired in the Institute is relevant to spintronics. We are using this knowledge in making contributions to major international spintronics R&D efforts."

Dr Simon Granville

TAILOR-MADE MAGNETIC SENSORS

We make magnetic sensors for niche applications where existing commercial sensors do not satisfy the need.

THE SCIENCE

We make thin-film devices—mostly thin-film magnetic devices or sensors—by depositing thin layers (somewhere from 100 nanometres and thinner) on solid substrates. They can either be deposited as single layers so the properties of a particular composition can be studied or deposited in alternating layers of magnetic and non-magnetic materials—a stack—for use as a sensor device.

IMPACT AND POTENTIAL

The Institute has the capability to make bespoke magnetic sensors that are tailored to solve the problems for which off-the-shelf sensors would not be so useful; for example, magnetic sensors that can alter their direction of sensitivity to the field. This is useful in applications in which a small field change against a large background field needs to be detected. This is vital in eddy current testing of metal objects where a large field may be applied to generate a smaller induced field that needs to be measured.

These sensors could also be tuned or controlled to detect an object's magnetic field, even in a large background magnetic field environment, or to look for multiple different magnetic signatures. That would lead to other potential applications in navigation, sensing buried metallic magnetic objects, or in monitoring the current in electric vehicle batteries.

CAPABILITIES

- Technique of depositing these films is magnetron sputtering
- Etch patterns or devices using an ion mill
- Wire bonder
- SQUID and PPMS systems
- Magneto-optical Kerr Effect (MOKE) to measure the magnetic properties of materials

THE PEOPLE

Dr Simon Granville manages the thin film deposition and magnetic properties labs, which include a SQUID magnetometer, PPMS, and MOKE equipment. He believes the institute is unparalled in New Zealand as a coherent team with expertise and capability in everything needed to take leading-edge materials science and engineering all the way to new tools and prototypes aimed at solving intractable industry problems.

ZERO-CO_2 PRODUCTION OF METALS AND OXIDES

Many manufacturing processes for essential industrial materials emit CO_2 and other environmentally harmful waste streams. These are by-products of the underlying chemical processes and accompanying combustion heating requirements.

THE SCIENCE

New ‘green chemistry’ methods for the processing of inorganic materials, such as metals and ceramics, are attracting plenty of interest worldwide. Robinson researchers are redesigning traditional materials manufacturing processes by taking a whole-of-systems approach that focuses on minimising emissions through changing the underlying chemistry.

The Institute’s flagship project is using hydrogen to eliminate fossil-based carbon from the industrial steelmaking process. Instead of CO_2, the by-product is, quite simply, water. This high-temperature reaction is performed in a high-temperature reactor which has been custom-built at the Institute. Other work is exploring new routes to producing critical materials like vanadium, as well as sintered technical ceramics and industrial inorganic compounds.

IMPACT AND POTENTIAL

In New Zealand alone, the steelmaking industry accounts for 14 percent of net national CO_2 emissions. Meeting future CO_2 emission targets will require minimising or eliminating carbon inputs from this industry. Our work has shown that this could be achieved using our alternative process technology, which employs hydrogen as a reactant and high-temperature electromagnetic furnaces.

The use of hydrogen not only creates opportunities to improve environmental sustainability, it also increases the purity of the final metal product and reduces the overall size of the reactor required. This has additional advantages for the steel plant owner, as it simultaneously increases revenue and significantly decreases capital costs.

THE PEOPLE

Dr Chris Bumby leads the Zero-CO_2 metals programme at the Institute. He recognises the unprecedented benefits that the Institute brings by having engineers, physicists, and materials scientists collaborating closely to accelerate progress on a complex problem. Novel experimental reactor designs are conceived, designed, built, and tested in house. Automation of purpose-deigned systems enables a wide range of conditions to be studied in detail and quickly.

“Our automated sampling system means reactor studies that typically took weeks to work through can now be done at the Institute in just a single day.”

Chris Bumby

CONTACT US

Robinson Research Institute is a world-leading team of 25 scientists and engineers who create and commercialise applications of high temperature superconductivity (HTS) and other technologies in conjunction with industry partners. Team members are multidisciplinary, and each shares the determination to see the results of scientific research applied directly into new technologies.

The Institute is recognised across the world as a pioneer in HTS. It is committed to developing national and international partnerships and is creating a network of companies that are working together to bring new technology to market. As well as superconductivity, the Institute is partnering with industry to develop new applications for magnetic sensors, new cryogenic and transformer technologies, and electric transport technology.

So, if your ideal partner:

- has academic and industrial breadth
- performs real-scale, commercially applicable research
- is commercially astute
- brings a team, rather than an individual, to solve your problems
- works with both research organisations and commercial entities

then get in touch with us at +64 4 4630080 or rri-admin@vuw.ac.nz, or contact the following people directly:

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