CAPABILITY

Each year the Crown Research Institutes receive Capability Funding through the Ministry of Research, Science and Technology to support and enhance long-term research capability. In 2008/09, we received $5.2m and we used it to fund a total of 26 projects.

Robots that "see"

Scientists and engineers in IRL's engineering innovations team specialise in automatic systems for handling and processing items that are of varying sizes, shapes and colours – a skill in demand due to New Zealand's reliance on primary products. Capability Fund money is going towards sharpening the intelligence of these systems still further with the addition of 3D vision. The team is working towards a prototype that can "perceive" the object it is working on and decide how best to process it so there is no wastage or damage. This work will provide a vital springboard for developing a range of robotic systems for processing sheep carcasses through IRL's involvement in Ovine Automation Ltd – the joint FRST/industry-funded programme to rejuvenate the New Zealand meat processing industry. The engineer heading the team, Patrick Lim, says another application for vision-guided robots is in horticulture. "Autonomous robots with 3D vision capability could navigate orchards and perform specialised functions in this sort of precision agriculture in order to get the best possible yields."

Finding the right tools

Our understanding of the future applications for nanotechnology is still rudimentary, because new phenomena are still emerging. Widening our understanding of the behaviour of materials at the nano level will be an important step in this, but that will not happen without the specialised tools needed for the job. IRL Capability Funding is supporting research into new tools for interacting with fluids at the nano and microscale. One line of research is using specialised glass capillary tubes to take up microscale droplets, enabling manipulation of particular liquids that are otherwise difficult to handle. Project leader Geoff Willmott says the research adds to our understanding of the fundamental principles of extremely small-scale fluidics, which will lead to new commercial opportunities. "At the moment, many of the applications in microfluidics relate to analytical chemistry, for example medical diagnoses. This work can help us contribute in these areas at the same time as discovering entirely new applications in, for example, industrial processes."

IP cores

Intellectual Property or IP cores are a way of implementing codified IP in the form of a signal processing algorithm into the hardware of an electronic device such as a digital signal processor, an Application Specific Integrated Circuit (ASIC) or a Field Programmable Gate Array (FPGA). IP cores are common in the ICT industry, but also have potential application in medical technologies and advanced manufacturing.

This Capability Fund project is aimed at developing a library of IP cores that can be taken up by New Zealand industry for use in products using FPGA technology. FPGA devices have become very popular because the development costs are lower than ASICs and they are easy to reprogramme after installation. By developing a choice of IP cores for industry, IRL can lower the cost still further while helping New Zealand companies adopt FPGA technology into their products. The research team is also working closely with a Wellington-based electronics design and testing company, i2M Labs, to ensure there is a critical mass of expertise in New Zealand on FPGAs.

One of the eventual goals of the IP cores project is to link it to IRL's broadband wireless research to establish a new sector designing and manufacturing components to process wireless signals in cellphones and other communications equipment.

Chemical metrology

New Zealand's reputation as a primary produce exporter depends on the purity of its agricultural products, and Capability Fund investment has gone towards developing the capability to detect and analyse chemical impurities that could affect exports. The initial work is on honey with the focus on identifying concentrations of tutin and hyenanchin, which result from bees harvesting honeydew from tutu plants, especially when there are few flower sources available. The

< Gavin Painter
– Research Scientist Carbohydrate Chemistry

honeydew containing tutin and hyenanchin is produced by vine hopper insects (Scolypopa sp) as they feed on the sap of the tutu plant. When bees harvest this in quantities, toxic honey can be the result, as happened in 2008 when nine people became sick from eating a batch of honey from the Coromandel Peninsula that was found to be tainted by tutins. The MSL project aims to build a set of reference materials that can be used as a standard for testing for these toxins in honey. MSL research scientist Laly Samuel, who is leading the project, says this will ensure laboratories testing for these toxins produce consistent results that are trusted by New Zealand's trading partners.

"The move to free trade rather than the quota system has meant more emphasis on quality of goods and, given concerns around environmental and health issues, it is essential our exports can be shown to meet those concerns when it comes to chemical residues. With standards developed for honey we can then move towards our ultimate goal of reference materials and standards for our range of exports based on primary products."

Electronic kilogram

The accuracy of most of the measures we rely on in commerce, in science and in our everyday lives – including length, time and temperature – are all defined in terms of fundamental constants derived from physics. The sole exception is the kilogram, which is still defined by a physical object – a platinum-iridium cylinder that for nearly 120 years has been held in an underground vault in Paris, along with six copies used to track its value. Unfortunately, the reference kilogram has apparently lost weight – 50 micrograms, or roughly the weight of a fingerprint. While that is neither here nor there for weighing a kilogram of apples, it is significant where precise measurements are required and where we now have the technology to make extremely accurate measurements. As a result the hunt is on to find a fundamental constant as the basis for the kilogram. Chris Sutton of MSL is one of the researchers seeking an answer. "The approach that we are working on is a watt balance that will link the kilogram to the Planck Constant – which is named after one of the founders of quantum theory, Max Planck," he says. "A watt balance allows us to relate mechanical power to electrical power by comparing the gravitational force on a mass with the force on a current-carrying coil in a magnetic field. This in turn will allow us to link the mass of the kilogram to the fundamental Planck Constant via quantum resistance and voltage phenomena."

Capability Funding has gone towards establishing the theoretical basis for this approach and on designing a watt balance experiment that uses an oscillating coil to determine the mechanical to electrical relationship. Besides being more stable and enduring than a material artefact, Chris Sutton says that having an unchanging fundamental constant as a reference for the kilogram would also be accessible by researchers at laboratories and measurement institutes around the world.

Nanoelectromechanics for new age electronics

For decades, the size of electronic devices, like computers, has been steadily shrinking – computers once filled a room; now they slip into a jacket pocket. However, each generation of electronic devices has brought with it manufacturing challenges and we are now at a stage where, if new devices are to be developed, we need to understand the basic principles of how electrons flow at the nano-scale. Quantum dots and carbon nanotubes are two materials seen as likely candidates for replacing silicon chips and copper wire and IRL is contributing to global efforts to research their behaviour and practical application in circuit boards. Using Capability Funding, MSL researcher Vladimir Bubanja has developed theories on the way electrons are transported through quantum dots and carbon nanotubes as well as how their quantum properties can be influenced and used in realistic circuits. "The results give clear guidance to engineers trying to build electron transfer devices using these materials," he says, "and the high accuracy of these devices means they could have application as quantum current standards and in the replacement of the artefact-based mass standard with defined values of fundamental atomic constants." Another potential application of the work is in better understanding electron transport in biological cells – something that could help researchers looking for new therapeutic drugs.

Researchers from Japan, South Korea and Germany are collaborating with IRL on designing prototype devices based on the work done under the Capability Fund.

< Nick Long
– Project Leader HTS Roebel Cable team

Towards new therapeutic treatments

IRL's Carbohydrate Chemistry Group, in collaboration with the Albert Einstein College of Medicine, has developed a world-leading capability in glycotherapeutics – new drug treatments based on carbohydrates. Capability Funding is now going towards opening up a new area of study – the therapeutic potential of glycolipids. Glycolipids are lipids or fats that are attached to a carbohydrate molecule. They are found on the surface of cells and play important roles in cell biology and immunology. Under the programme, a team of IRL carbohydrate chemists is synthesising glycolipids from the cells of pathogenic bacteria and, working with biologists at the La Jolla Institute for Allergy & Immunology (LIAI) and the Universities of Wisconsin (US) and Birmingham (UK), monitoring what effect these compounds have on the immune system. Project leader Gavin Painter says some of the most promising work has been in using synthesised compounds from the cell walls of Streptococcus pneumonia, which, as well as causing pneumonia, is also the bacteria involved in pneumococcal infections such as meningitis, acute sinusitis, middle ear infection and peritonitis. "The project is aimed at increasing our understanding of how cell wall glycolipids from pathogenic bacteria affect the cells of the immune system and why in some cases the immune system is alerted to clear the bacteria from the body while in others it tolerates the infective material, leading to the development of infection. By working with these leading-edge research groups, we get an insight into an area of therapeutics that we might otherwise not have and that can then feed into our work for FRST-funded therapeutic drug programmes that are delivering drug candidates for New Zealand's pharmaceuticals industry," he says. "Importantly, this particular project has not only allowed us to strengthen our international collaborations and promote the profile of IRL, it has also involved researchers with specific skills from across the company, including those working on fermentation, analytical development, extraction, and synthetic chemistry. This combination of expertise will help IRL take a leading role in setting new boundaries to the project in the coming year."

Identifying opportunities for spintronics

Spintronics – short for spin transport electronics and also known as magnetoelectronics – is an emerging technology that uses a new class of materials that take advantage of the spin of electrons for use in a new range of electronic devices. Conventional devices use the transport and storage of the "charge" produced by electrons, but an IRL team is exploiting the characteristics of spintronics to create a new generation of magnetic sensors that are more sensitive, smaller, energy efficient, precise and reliable. With funding from FRST, the spintronics team, led by Grant Williams, is developing thin and thick film magnetic sensors for electronics, non-destructive testing and security applications.

Capability Funding is going towards allowing the team to work with New Zealand industry to map out how this research will be used to design, develop and manufacture new products. Grant Williams says this early engagement with companies is allowing IRL to ensure that its R&D is meeting industry needs. "We're still a couple of years away from producing a working prototype, but IRL has brought together a group of half a dozen companies, including companies that build sensors, others that will add their technology to create high-value sensors, and those who use sensors to create high-technology products," he says. "To date, industry has made it clear that they see huge potential for this new generation of sensors and have indicated they will participate in product development, provided that researchers can come up with a prototype that meets their needs in terms of cost, performance and reliability."

The spintronics team involves researchers from Victoria University and Canterbury University and includes funding from an IRL-led Magnetic Sensors programme, two Victoria University-led rare earth nitride programmes, and objectives within the MacDiarmid Institute.

Fermentation for biofuels and probiotics

In recent years, IRL has been developing expertise in aerobic fermentation – a fermentation process carried out with oxygen – as part of a research programme funded by FRST to extract high-value lipids from a range of micro-organisms.

Now, using Capability Funding, fermentation research at IRL is moving into two new areas – anaerobic (where oxygen is not present) fermentation of bacteria and the photobioreactor culture of algae. The money is going initially to develop robust pilot-scale production systems for both these techniques. The research team will also work with New Zealand research partners to identify micro-algae and bacteria to be used in each process. Project leader Jason Ryan says there are several potential applications for these technologies. "In the longer term we're interested in using anaerobic bacteria to produce liquid transport fuels such as ethanol and butanol from waste products. Our initial focus is on using glycerol waste from biodiesel production but there is potential for turning waste from a variety of our primary products into biofuels," he says. "The other application is in new high-value ingredients for use in cosmetics and probiotic products and these could be very useful for New Zealand's growing natural products sector, which is always on the look-out for new products for export."

Having capability in both anaerobic fermentation and photobioreactor production will also help other IRL science programmes and, in particular, research by Carbohydrate Chemistry into biological compounds known as glycoconjugates in pathogenic bacteria and in beneficial gut and probiotic bacteria.

The project is also contributing to Jason Ryan's PhD, which is being sponsored by IRL and by the Industrial Research Charitable Trust.

In search of an industrial cryocooler for HTS

HTS technologies need to be kept at temperatures below -200˚C for optimum performance. If they are to be used widely in industrial settings, that cooling system, or cryocooler, needs to be robust, highly efficient and affordable. Money from the Capability Fund has gone towards developing a capability in IRL in pulse tube technology for cryocooling applications. This approach uses a plug of gas as a virtual expansion piston, meaning there are no moving parts in the coldest part of the refrigerator – the cold head – hence lessening the need for maintenance. The work builds on IRL's considerable success in producing another component of a cryocooler, the pressure wave generator that provides the energy to do the cooling. IRL's approach has been to use a flexing membrane, or diaphragm, to seal the pistons that produce the pressure waves to drive the gas refrigeration cycle that brings down and maintains the cold head at the necessary temperature. IRL associate company HTS-110 has already commercialised this pressure wave generator and four of these have been supplied to French company Air Liquide – a partner in IRL's cryocooler research – who have coupled the pressure wave generators to their own pulse tubes and incorporated the coolers into a cryogenic CO_2 scrubber. At a recent international conference, the company reported that the IRL pressure wave technology had performed better than other linear motor systems they had tested.

Alan Caughley, leader of the cryogenic refrigeration programme, says, "Our end goal is to make available to New Zealand industry a cryogenic refrigeration technology. This is critical to enabling the widespread adoption of HTS. With our diaphragm pressure wave generator, coupled to a pulse tube developed internally and/or sourced by in-licensing, New Zealand will have a robust, efficient, easy-to-use and cost-effective cryocooler. This development has also opened up other commercial opportunities in areas such as small-scale gas liquefaction and will become a significant business for New Zealand in its own right."

< Paul Benjes
– General Manager GlycoSyn