SCIENCE FOR TECHNOLOGICAL INNOVATION

Kia kotahi mai – Te Ao Pūtaiao me Te Ao Hangarau

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KIA KOTAHI MAI: TE AO PŪTAIAO ME TE AO HANGARAU

MISSION LAB

APRIL 2018

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Mangopare (Hammerhead shark): uniting traditional Māori knowledge with modern science

Science for Technological Innovation - Kia Kotahi Mai: Te Ao Pūtaiao me Te Ao Hangarau (SfTI) aims to enhance the capacity of Aotearoa-New Zealand to use physical sciences and engineering research for economic growth, primarily through export-driven innovation in areas of strength and competitive advantage. The Challenge has a mandate to deliver bold, exciting science to create new market opportunities for New Zealand firms. It involves researchers from local and international universities, Crown Research Institutes and independent research organisations, as well as partnerships with iwi, corporates, and local SMEs.

An important aspect of the work has been consulting with industry representatives about where New Zealand's leading science and engineering researchers should be focusing their attention. The current document contains discussions from this year's SfTI Mission Lab.

The Mission Lab was an opportunity to bring together technology leaders from a number of sectors and disciplines who could offer a future-focused perspective in exploring the next opportunities and challenges for Science for Technological Innovation.

The intention was to identify the technology missions that will support the next step change in our economy, and help shift the conversations and elicit the best advice on which opportunities Aotearoa-New Zealand can exploit in the hi-tech sector over the next 10 – 20 years. To this end we explored such questions as 'what science is going to make the greatest difference for Aotearoa-New Zealand's economy?' and 'what new disruptive technology is going to most excite Aotearoa-New Zealand's researchers in the future?' The result was a wide-ranging discussion about New Zealand's opportunities, and ideas for how science researchers can continue their work.

Inside this report, you'll find an outline of the work achieved through the SfTI Challenge to date; this shows the progress already made. Updates are also included on the state of play of various key technologies. A summary of the themes discussed by participants is provided, followed by the six Spearhead research ideas generated.

SECTION 1:
SFTI CHALLENGE OVERVIEW

The Science for Technological Innovation - Kia Kotahi Mai: Te Ao Pūtaiao me Te Ao Hangarau (SfTI) National Science Challenge aims to enhance New Zealand's capacity to use physical sciences and engineering for economic growth. The intention is that through more carefully focused and connected research efforts, a more technology-driven and prosperous economy will result.

While the government funds many levels of scientific research, the 11 National Science Challenges are tasked with generating innovative new ideas where there is a degree of uncertainty. Ultimately, research funded under this initiative aims for excellence and long-term impact.

The Challenge currently has five portfolios (see www.sftichallenge.govt.nz for more detail):

- Portfolio 1: Building NZ's innovation capacity
- Portfolio 2: Agricultural and environmental technologies
- Portfolio 3: Health and medical technologies
- Portfolio 4: Smart services
- Portfolio 5: Materials, manufacturing processes and applications

While future mission-led spearhead research projects do not have to fit these portfolios, they do need to relate to at least one of our themes:

- Sensors, Robotics and Automation
- Materials, Manufacturing and Design
- IT, Data Analytics and Modelling
- Vision Mātauranga

VISION MĀTAURANGA

All government funded research, including SfTI, is underpinned by Vision Mātauranga (VM); this approach requires researchers to connect with Māori as individuals and groups, and in terms of special knowledge and cultural values. The Challenge currently has one new Spearhead in development that will be VM-led, that is, for Māori, by Māori, but does not exclude non-Māori. The mission statement of Vision Mātauranga:

To unlock the innovation potential of Mäori knowledge, resources and people to assist New Zealanders to create a better future.

CAPACITY BUILDING

Another important aspect of SfTI is the focus on building researchers' capacity to engage with those outside the research community, including Māori and industry, in order to accomplish mission-led research in collaboration with partners. To a degree, this process has been an experiment in industry-led mission development.

SECTION 2:
SFTI RESEARCHERS CREATING NEW SCIENCE & TECHNOLOGY

THE RESEARCH

The SfTI Programme allocates funding to two levels of research: large Spearhead projects, and smaller Seed projects. This section provides an outline of the work being achieved.

Spearhead Research

Seven Spearhead Projects are already underway. The first group of five commenced in 2016:

1. Building New Zealand's Innovation Capacity
2. Inverting Electromagnetics
3. Medical Technology – Home and Community Care
4. Data Analytics Developing Industrial Decision Models
   - Track 1: Large Industry - Supply-chain Optimisation
   - Track 2: Manufacturing - Electricity Procurement
   - Track 3: Māori Business - Identifying shareholders of Pareninihi Ki Waitotara
5. Next Generation Additive Manufacturing

A further two Spearheads were funded from mid-2017 and were developed during last year's Mission Lab.

6. *Karetao Hangarau-a-Mahi*: Adaptive Learning Robots to complement the human workforce sits within the Sensors, Robotics and Automation Theme.
   - Researchers will seek to develop new paradigms in robot autonomy and adaptability, including predictive environmental sensor fusion, and automatic improvement of AI-based interpretation of data. Rather than focusing on isolated robots solving single tasks, the research group will investigate workforce robots that could 'communicate', learn, and collaboratively work alongside humans. The programme will investigate 'non-written cues', and the use of icons to communicate and exchange information.
7. *Precision Farming Technology for Aquaculture* will see researchers from the Cawthron Institute, Auckland, Victoria and Canterbury Universities, the New Zealand Product Accelerator and Eco Research Associates collaborate.
   - The project seeks to develop technology for use on coastal and offshore aquafarms that enables remote decision-making, increased sustainability and productivity, and creates a path for greater automation in the future. Sensors will feature in this research, and achieving underwater and remote real-time communications is a particular challenge.

Two additional Spearhead directions are currently in development:

The Personalised Value Chain (PVC) has recently been refined enough to call for Expressions of Interest from researchers. At this stage, the direction includes three potential research strands which are aimed at creating novel technology that will help strengthen relationships and understanding directly between sellers and buyers in ways that empower both sides of the market:

- How can we empower consumers to protect their privacy while they are online, thereby creating better ecommerce options and experiences?
- What are the defining characteristics of establishing trust using a Mātauranga Māori approach and how might we apply these principles to establishing online trust to strengthen relationships between (NZ) sellers and global buyers?
- How can we make accurate predictions about consumer behaviour and demand when we have limited and/or poor quality data?

Ātea (Digital Marae) is still being refined. Researchers will aim to provide an interactive platform for developing contemporary indigenous knowledge. The project will be a learning environment that is hoping to connect the past and the traditional, with the future of modern Te Ao Māori (Māori world) as Māori wish to define it. It may be a place to transfer cultural knowledge and values, record history, and create a space where cultural identity and tikanga can be strengthened and transferred intergenerationally. Ātea will be led by and for Māori but will be inclusive and aim to add value to Aotearoa-New Zealand as a whole. There are three current foci for the research:

- Te Reo: about recognising, translating, synthesizing, understanding and responding in te reo.
- Connecting people: about using artificial intelligence, virtual reality, and augmented reality for connecting people, across time, place, and history.
- Utilising a Kaupapa Māori methodological approach for digital content, and mātauranga; for example, for content creation, data governance and sovereignty, Pūrākau (story telling), and blockchaining.

Seed Research

Twenty eight Seed Projects are in play or have already been completed - these are smaller, one-three year projects that are either standalone or may be extended into larger pieces of work. The first round included ten Seeds across the range of Themes and Portfolios:

A giant leap for small displacements	Te Tāhū o te Pātaka Whakairinga Kōrero: Next Generation Indigenous Knowledge
Magnetic silver clusters - a disruptive technology in bio imaging	A self-healing silicon electrode for lithium battery applications
Mechanically induced drug release	Golden Polymer for Enriching Biogas to Biomethane
Nitrate Sensor Arrays	Algae-derived food supplement
Controlling spray droplets in flight: new science enhancing innovative capacity	Enabling sustainable economic development with advanced additive manufacturing of wood

In the second round, a total of 18 Seed projects were funded and began in mid-2017:

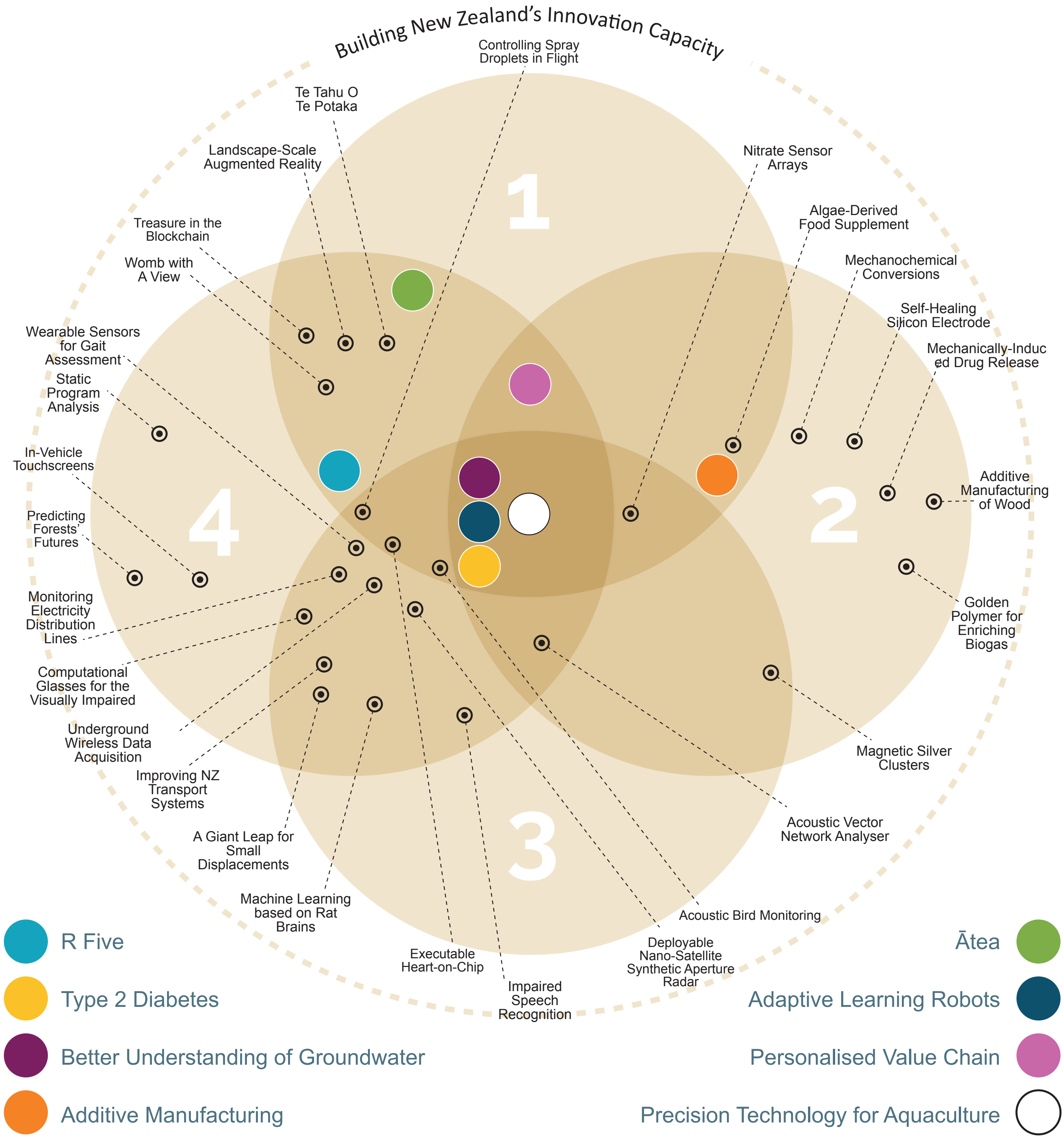
In-Vehicle Touchscreens: Improving Human Performance and Reducing Attentional Demands - Developing new understanding of touchscreen interaction during vibration, and improving interaction with touchscreens in vibrating environments is the aim of this project.
Data analytics to enable wide-area monitoring of electricity distribution lines - Use of new, automated data-analytics and modelling to extract information from 3-dimensional solid state magnetic field sensor measurements.
Mechanochemical conversion of biomass into commodity chemicals - Researchers will look to convert suberic acid, a compound present in cork and castor oil, into phthalates, and to transform cyclopentanone, a compound attainable from agricultural waste and forest residues, into adipic acid.
Closing the Gaps in Static Program Analysis - Poor software quality and vulnerabilities can be exploited for malicious activities. Static Program Analysis, where bugs and vulnerabilities are detected by models extracted from code without executing the program, will be the focus of this project.
Executable Heart-On-Chip for validating cardiac devices against drug effects - A project to develop technological innovation for pacemaker certification that accommodates drug induced effects.
Underground wireless data acquisition network using Low Power Wide Area Network - Focussing on ensuring long term, reliable, wireless data acquisition by investigating underground agriculture sensing.
Womb with a view: Software connecting pregnant women and fetus - Aimed at encouraging pregnant women to quit smoking, this project will develop a 3D model for web pages and mobile devices that demonstrate how smoking impacts their own, and their unborn children's, circulatory systems.
Wearable sensors for gait assessment in lower extremity disability population - A project to take a novel approach to address limitations of current 'best practice' rehabilitation for gait disorders by exploiting advances in wearable sensors and computational modelling.

Machine Learning Based on Rat Brains - Researchers will seek to identify models of learning based on rat-neuroscience to develop new artificial intelligence (AI) algorithms.
Modelling and improving emissions/energy efficiency in NZ’s transport systems - This project will look to model vehicle emissions in strategic transport modelling tools.
Acoustic Vector Network Analyser - This project aims to improve measurement of object acoustic properties eg the acoustic permeability of pasture as a function of its dry matter yield.
Landscape-scale augmented reality: enhancing public understanding of our cultural heritage - Potential economic and social impacts of this project include enabling increased cultural understanding by augmenting virtual reality.
Deployable Nano-Satellite Synthetic Aperture Radar for Monitoring NZ’s EEZ - Developing underlying science and technology needed to provide NZ with an overhead monitoring capability using space-based assets will be the focus of this project.
Computational Glasses; Head mounted displays for the visually impaired - The project will develop prototypes for computational glasses that analyse the environment and change it to compensate for user impairment.
Novel Approaches for Impaired Speech Recognition - Researchers will seek to develop adaptive personalised speech systems recognising individual impaired speech and generate intelligible speech.
Secure, shared and collaborative: treasure in the block chain - The distributed ledger technology known as ‘Blockchain’ shows considerable promise for use in secure, distributed systems of collections of information across traditional boundaries.
Distance and Direction Estimation for Acoustic Bird Monitoring - Estimating population densities by locating bird calls using mathematical and statistical methods.
Visual recommender technology for exploratory analytics: predicting forests futures - This project will explore the potential to use visual recommender technology to analyse complex spatiotemporal data sets.

Figure 1 illustrates where each of the Spearhead and Seed projects fit within the Challenge's four Themes. We can see a concentration of projects falling within IT, Data Analytics and Modelling, however, more often than not, this is being used to enhance other science streams particularly Sensors, Robotics and Automation.

Spearheads and Seeds by SfTI

1. Vision Mātauranga
2. Materials, Manufacturing and Design
3. Sensors, Robots and Automation
4. IT, Data Analytics and Modelling



SCIENCE PANEL REVIEW

In order to assess the quality of the research the Challenge is funding, SfTI initiated its first Science Quality Review in October last year. The review panel travelled the country to meet with key researchers from all five initial Spearheads and ten 2016 Seed projects.

Panel members:

1. Dr Colin Knox (Chair) (NZ) - formerly of Auckland University of Technology and Te Wānanga o Raukawa, and Advisor on Vision Mātauranga.
2. Prof Jennifer Loy (AUS) - School of Design, University of Technology Sydney.
3. Prof Paulo Desouza (AUS) - Commonwealth Scientific and Industrial Research Organisation (CSIRO), Canberra.
4. Prof Shaun Hendy (NZ) - Director of the Te Punaha Matatini ('Big Data' Centre of Research Excellence) a Centre of Research Excellence, and a Professor of Physics at the University of Auckland.
5. Prof Anthony Guiseppi-Elie (USA) – TESS Professor, Department of Biomedical Engineering at Texas A&M University.

The Terms of Reference for the review were to assess:

- the quality of the science and its contribution to the SfTI mission;
- the effectiveness, international standing and impact potential of the current mission-led scientific spearheads and seed research projects;
- the effectiveness, international standing and impact potential of the 'Building New Zealand's Innovation Capacity' portfolio;
- the efforts to integrate Vision Mātauranga into the research projects;
- the relevance of the science to New Zealand's long-term economic goals; and
- the composition of the research team given the 'best teams approach' to deliver the science.

The panel's findings were overwhelmingly positive, and commended the Challenge's approach to creating a research programme which incorporates Vision Matauranga, ensuring that one of New Zealand's unique characteristics is capitalised on. Further, the impetus to collaborate and build capacity was clearly paying dividends, and could usefully be extended further. Panel members were impressed that the majority of individual projects were both 'stretching' science and had an eye towards commercialisation. Feedback provided by the panel is currently supporting the SfTI Board's decision-making and ongoing planning.

SECTION 3:
SCIENCE & TECHNOLOGY DEVELOPMENTS

New technologies and innovation continue to change every aspect of human life. Increasingly, seemingly disparate strands of tech are being interlinked to create new and better experiences for consumers; this convergence is set to increase exponentially over the coming years. Technology will soon be ubiquitous and seemingly invisible.

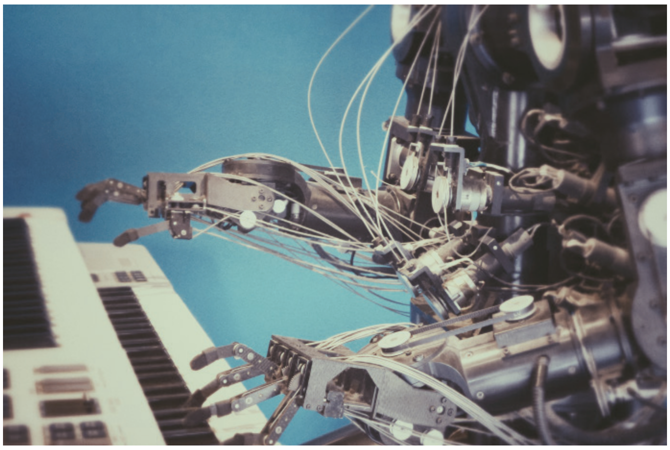
How can New Zealand capitalise on new science and technology possibilities? Understanding the changing innovation ecosystem and what is already possible is a vital first step because we need to evaluate whether research ideas under consideration constitute new science and technology. Additionally, whether research outputs would have clear value to New Zealand is an important consideration. The Challenge is looking at long-term value potential and national distinctive competency potential.

An outline of some key areas of science and technology applications are listed below.

THE SCIENCE

Artificial Intelligence and Machine Learning

Artificial intelligence (AI) is beginning to impact everything. Cognitive technologies enable the very personalised experience people now enjoy (and take for granted) online through analysing, and learning from, the vast amounts of data users generate. Natural language processing converges with pattern recognition and analytics to move marketing departments, for example, from thinking in terms of market segments to creating individualised journeys for every customer. Virtual assistants, chatbots, algo-traders, facial recognition, predictive analytics among many others, are all outcomes of AI and machine learning technology. The future is very personalised.



New Zealand's Orion Health has just announced a new offering called Amadeus Intelligence, which applies Machine Learning to increase hospital efficiency and improve patient outcomes. Ian McCrae, recently told media how artificial intelligence is building upon big data:

> *"The last decade has been focused on integrating IT systems and capturing massive amounts of information about patients and their environments. The next decade will be to connect all that data and use machine learning for daily healthcare decisions, driving improved care, operational efficiencies, and cost effectiveness."* **(Ian McCrae, CEO - cio.co.nz)**

Some consider that machine learning-based automation, once it reaches a tipping point, will have as big an impact on the world as cloud computing did. Where lean management achieved impressive efficiencies across industries post-GFC, and early adopter businesses experienced significant competitive advantage, automation enabled by machine learning will bring the next wave of value. First movers will benefit.

Robotics

Advancements made in robotics are highly related to concurrent improvements in AI and machine learning, as well as sensors, IoT and vision technology. Manufacturing is one key use for robotics.

The International Federation of Robotics reports that the density of robots in manufacturing is rising around the globe, although the distribution is far from even. The key measure is the number of robots per 10,000 employees; the global average currently sits at around 74. South Korea is the greatest user of automation with 631 robots per 10,000 employees, with Singapore the next highest on 488. New Zealand uses just 49, while Australia is slightly higher at 83.

This growth is in large part due to technological innovations in the manufacturing ecosystem such as the Industrial Internet of Things (IIoT) which render manufacturing sites more adaptive than ever before. While robots are being readily adopted in the automotive, electronics and metal industries, food manufacturing is relatively slow on the uptake.

Strong growth in demand is predicted for easy-to-use collaborative robots, and small and medium-size manufacturers are expected to start using robots en masse as improvements enable greater flexibility through machine learning. When it comes to food and beverage manufacturing, ubiquitous problems such as traceability, quality control and staffing can all be mitigated through the use of robotics.

IoT, IIoT and IoE

The Internet of Things (IoT) allows real-time feedback from physical objects via the cloud. In terms of applicability, it could be relatively simple with sensor information being used to communicate limited data between two discrete points (for example, a household fridge could order groceries online from the local supermarket), or the technology can be applied through a citywide network of sensors capturing and analysing vehicle data, and then controlling intersections to maximise traffic flows. Consumers are more digitally connected today than ever before, and this is continuing to increase through greater ownership of smartphones and tablets, and the introduction of wearables such as fitness trackers.

But technology is heading towards connecting people, processes, data and objects together in ways that don't just 'describe', but actually add value by creating richer experiences and new capabilities. The Internet of Everything (IoE) refers to this near reality where billions of objects have sensors that are networked together to realise as yet unknown possibilities.

Virtual Reality

The internet has created a vast network of information that anyone can access at any time; synthetic reality will create a network of easily accessible presence-based experience.

Virtual and augmented reality are already available to consumers at varying levels of authenticity. The technology is usually accessed via some type of screen or headset and is rapidly being refined in terms of realism. As with all other technologies in this section, artificial reality's journey into the mainstream is being supported by developments in other areas – after spending 25 years confined to expensive laboratories, the arrival of the smartphone suddenly provided affordable VR hardware to the masses.

Mixed reality is arguably the most exciting member of the synthetic reality family, in that artificial components are superimposed onto and appear to interact with reality, heightening the sense of a presence-based experience. Magic Leap is one company focusing on this technology: the startup has raised almost US$1.4b in capital and counts Weta Workshop amongst its partners.

We will also soon be seeing artificial reality in manufacturing as sensors and IIoT allow digital twins for real robots and other machinery to be created, primarily for monitoring and maintenance purposes.

Blockchain

Blockchain is probably best known as the foundation on which the alternative currency Bitcoin is administered. In essence it is a distributed, permanent ledger system that allows multiple parties to record transactions. Its primary advantages lie in its permanence, low cost and transparency.

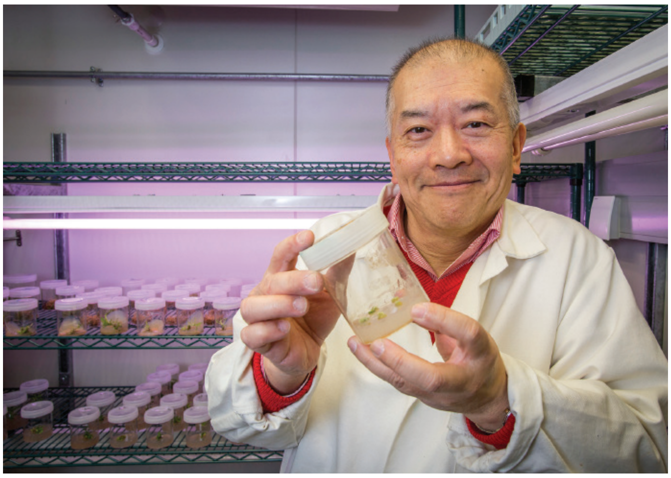
Currently, private blockchain networks are being used in the financial sector and this same approach could be adopted in other industries too. For example, IBM is working with Tsinghua University and Walmart to create a superior food traceability system for China.

Blockchain might be described as the next 'big thing' with both large established corporations and small startups seek to add value to all kinds of industries using this technology, for example by disintermediating business transactions to increase efficiency, or document provenance and fight food fraud.

AREAS OF TECHNOLOGY APPLICATION

Agritech

A growing global population set to reach 10 billion by 2050, as well as demographic shifts and climate change impacting access to natural resources all signal an evolving need to develop better technology to grow more food. In 2015, agriculture was identified by the McKinsey Global Institute as the least digitised sector in the US economy, however, there has since been huge investment in agritech across multiple fronts, from cellular agriculture and the development of novel urban farming systems, to the use of sensors and satellite imagery to optimise on-farm decision-making. Blockchain is also being applied to the food supply chain to provide confidence in provenance. Which strands of agritech should New Zealand be most interested in?



Cellular Agriculture

Cellular agriculture continues to make huge leaps, with numerous startups working to create synthetic foods that are safe, delicious and cheap. The main focus of this technology is really about reinventing protein … without the animal slaughter or environmental degradation that are an inevitable part of today's practices; some have called it the 'alt-protein movement'. Its two strands are plantbased (for example, Impossible Foods applies fermentation to plant protein to create a meat-like product), and cultured meat (for example, Memphis Meats grows real meat from animal cells).

An important aspect of this type of agriculture is that it takes place inside a building using nutrient solutions and scientists, with no need for the wide open spaces New Zealand beef and lamb relies on. What this will mean for our meat exports bears careful consideration.

Novel Urban Farming Systems

Highly aligned to cellular agriculture, there is a new movement towards creating systems that allow food to be grown in small spaces, using minimum resources. A shipping container can be turned into a fully autonomous 'farm' with sensors, controlled lighting and heating, and software. It can allow small businesses in the middle of megacities to set up to grow fresh vegetables to sell locally, or a growing wall can be installed in a restaurant or café, similarly supported by technology. New technology is also being applied to using (food) waste from other industries to support aquaponics or insect farming.

If this kind of distributed food production becomes popular around the world, what impact might it have on New Zealand, which relies so heavily on exporting meat and dairy?

Environment/Sustainability Technology

People around the world are starting to concede that business as usual is no longer an option; we must find new ways of doing things, and virtually no corner of human life will be left unaffected. Because this issue is ubiquitous, envirotech can include low emissions tech, clean water tech, and climate change tech … and the list goes on.

There are many instances of efforts to increase sustainability around the world, and science and technology are at the forefront. For example, the global interest in electric vehicles (EVs) has led to the need to improve batteries. They would ideally be lighter, safer, more powerful and last longer, if EVs are to become ubiquitous. Work is currently being undertaken to achieve this through replacing lithium with sodium. Toyota believes this solid-state battery technology could double the capacity of today's lithium-ion batteries, and they are investing significant resources into perfecting the science.

Innovation and transformation consultant, Rebecca Mills, equates sustainability with innovation, and says businesses of the future can't separate the two. She considers that in New Zealand while there is a degree of uncertainty about how tech is going to impact industries, and jobs in particular, she suggests there are incredible possibilities available for those who are prepared to think and act differently.

> *"There are glimmers of understanding of the extent of the opportunity, and given the extent of that opportunity, this very small light would benefit from a great big spotlight being shone on it."*
> **(Rebecca Mills)**

Rebecca notes that New Zealand can and should attract the world's best innovative thinkers to live and work here. If science and technology is the engine of sustainability, it needs to be underpinned by a particular lens or perspective of opportunity rather than risk, and the acknowledgement that business is well placed to take the lead with support from government as necessary.

Space tech

Space tech encompasses a broad range of areas, from observing and understanding celestial bodies, to developing space systems that enable space travel and exploration. A significant branch is the use of satellites for communications and Earth observations.

Until recently, most satellites launched were large and expensive, and primarily funded by government to support military activities or weather forecasting, for example. However, in the last decade, especially over the past five years, there has been a convergence of technologies that has set the scene for space to be commercialised and democratised through lowering costs and shortening the build and launch process.

Photo: RocketLab

Companies like RocketLab and SpaceX have dramatically lowered satellite launch prices and as a consequence, created an entirely new customer base. In fact, when SpaceX published their launch budgets just a few years ago, it enabled entrepreneurs to put together well-costed business plans for satellite-based initiatives.

While RocketLab is currently enjoying a high profile, the infrastructure required to support a space tech industry here is only just getting started. The New Zealand Space Agency, formed in 2016, is responsible for setting policy and regulation, and is currently working on agreements to access other governments' satellite data. Just last year, the Centre for Space Science Technology (CSST) was established. The organisation is a Regional Research Institute tasked with bringing earth observation data into New Zealand's economy.

Spire Global have launched around 50 satellites to track the world's shipping vessels. For the marine industry, satellites have multiple uses, including: tracking fishing vessels, monitoring territorial waters, early weather warnings, and port traffic management.

Planet is another space tech company – it launched over 100 satellites in 2017, enough to map all the landmass on Earth on a daily basis. The company is now developing the analytics tools to allow customers to extract whatever data they need for their own decision-making.

Steve Cotter, CSST's CEO, discussed the state of (satellite-based) Spacetech in New Zealand. At its heart, satellite data is about supporting critical decision-making on the ground. Satellites provide multi-spectral imaging, including infrared, which can be useful on its own, but perhaps the true magic of this technology is revealed when the relatively low resolution images are paired with groundgenerated data, for example from sensors or high resolution cameras.

While CSST doesn't operate its own satellites, it works with providers to make data available to researchers and businesses. In particular, Steve consults with industry to understand their needs and advise on how satellite data can assist. He says the current situation in New Zealand is a low level of familiarity and use of earth observation data meaning most of those he speaks with are initially unsure of how satellites could be relevant to them. However, businesses of all kinds are keen to embrace the technology once they learn of the potential benefits. There is almost no end to the advantages presented by satellite data. It can measure snow pack, making it useful for tourism and hydrogeology; it can assist the mining industry in finding minerals; and it can monitor crops to assist farmers with their decision-making. Satellite imagery can also help with infrastructure planning after natural disasters for instance, by mapping damage.

Steve notes several reasons why New Zealand should focus on Earth Observational Space Tech. First, our geography is extremely varied with a long coastline, mountains, pastures, lakes and urban areas of varying density. While our climate is considered mild, our defined seasons are a plus. This scenario provides us with the opportunity to test satellite-based solutions within all but the harshest environments, meaning the technology developed here could be applicable across the globe. Further, experiments can be carried out on a smaller scale and at less cost that might be possible elsewhere. The more direct benefit, however, is simply to make better and more ubiquitous use of available data and analytics to support a range of New Zealand industries, including tourism and agriculture.

On a more human-oriented level, Steve notes that New Zealand's nascent space industry would be a definite drawcard for expats who have had to move overseas to explore their passion for space. The Centre has already enticed their new Director of Research, a Kiwi, to return home after years working overseas, including a role with NASA.

Medtech

When it comes to medtech, one of New Zealand's biggest challenges may be to translate clever new innovation and technology development from the lab into the market place. This country has a number of niche areas of focus, and for companies able to make the leap into commercialisation, there's a good track record of global success.

There is already a healthy set of medical technology companies in New Zealand. Perhaps the best known is Fisher & Paykel Healthcare, which currently employs over 4,000 people across 35 countries, and reported a profit of $81m for the first half of FY 2018. Other successful local companies include Pacific Edge, which saw significant growth in the North American market due to a new product release; revenue increased by 32% on 2016 (TIN Report 2017).

Technology is starting to be used to support Māori health outcomes. Dr Lance O'Sullivan's Navilluso Medical created iMOKO, a digital health platform that supports community-based identification and treatment of a range of health problems that may otherwise be missed. It comes in the form of an app and links with pharmacies to make sure patients can easily access prescriptions. More recently, the company launched a pop-up virtual medical centre in Patea, Taranaki. Whānau Tahi also uses digital to support Māori health. Their software connects whanau and health professionals in a way that allows people to take control of their own health. Both companies were featured in last year's TIN Report, with Whānau Tahi being named a Hot Emerging Company.

An obvious opportunity exists in data and analytics, machine learning and using AI in the personalisation of medicine. The growing movement towards community care means that anyone developing medtech for the home must factor in use by non-medically trained individuals, including patients and their families; this means tools must be extremely user friendly, and interoperability is a key consideration to ensure community and medical professional connect seamlessly.

Another interesting aspect of devolving responsibility for healthcare to patients themselves is: how do you motivate people to live a healthy lifestyle?

In New Zealand strong collaboration between the MedTech CoRE and Auckland Bioengineering Institute (University of Auckland) has resulted in a high level of excellence in creating physiological computational models with measurement and analytics capability. As computational power increases and costs fall, the time may be ripe to commercialise tech tools that simulate organ functioning at the molecular and physiological levels. For example, personalised medicine could be advanced by combining this area of expertise with science that falls within SfTI's remit, such as sensors and data analytics.

Additionally, it may be natural for New Zealand to seize on the crossover between medtech and Agritech in the area of animal health management. For example, nutrition modelling could be employed to observe how gut bacteria react to various stimuli so that feed can be personalised to individual animals, which in turn maximises yields or meets the nutritional needs of humans eating animal products.

SECTION 4:
MISSION LAB DISCUSSION: NEW ZEALAND'S OPPORTUNITIES

As a continuation of SfTI's commitment to connect with industry, the Mission Lab is intended to be high profile and based on open engagement with business and Māori economic thought leaders.

The Mission Lab took place in Auckland over a full day on 13 March 2018. Around 30 participants from industry and government contributed to a series of questions posed by facilitator, Rod Oram, about New Zealand's potential for using technology to achieve better outcomes economically, socially, culturally and environmentally. Participants were selected as visionary industry and Māori leaders with a long term and New Zealand-wide view of what new physical sciences and engineering technology should be developed for New Zealand's future economic growth. SfTI management team members were also present as observers and to help discussions at each table.

First, participants were invited to think reasonably broadly about New Zealand's opportunities to use technological innovation most effectively. Several themes became evident, including: small niches, sustainability, and Mātauranga Māori, as well as the need to support top talent and acknowledge the role of integration (on many levels).

This section documents the wide ranging participant discussions from the day. The following section provides introductions to six Spearhead research ideas as well as suggested questions and considerations that will be further explored as concepts are developed into potential SfTI projects.

New Zealand's Opportunities

SMALL NICHES

It was acknowledged that multinationals are already investing heavily in the big obvious problems; this leaves small niches, in clever science and in extending existing knowledge, that are too small for heavily resourced organisations to focus on. In particular, we need to think about science and technology that is relevant to us and can create a higher proprietary export value than selling commodity food does.

There are already examples of New Zealand tech companies attacking these gaps successfully in the marketplace. StretchSense, which has raised significant overseas investment, is behind the ZOZOSUIT, which measures consumers' body dimensions and communicates this data to online garment retailers so that new purchases are guaranteed to fit well. Online clothing suppliers' biggest expense is customers returning clothes that do not fit properly, so this new technology solves a significant problem for them. The underlying technology has multiple potential applications.

Other ideas include further work in IoT and devices that talk to each other. New Zealand has already shown itself to be skilled here, so small, low cost, clever devices that are easy to manufacture could work well.

Short run manufacturing also has possibilities, particularly where collaborative robots are involved. There is still work to be done in developing better AI that can reduce reprogramming requirements between tasks.

3D and 4D printing similarly offer niche opportunities. Materials, particularly biopolymers, seem to be an area of potential where biodegradability or other novel factors could be incorporated, for example. New Zealand has unique knowledge that would allow us to look to forests for raw materials such as lignin (some work is already happening within SfTI here). Aircraft spare parts may be another interesting avenue for printing.

SUSTAINABILITY

It is now widely recognised that we need to make significant improvements in terms of sustainability, and we need to do it quickly. A recent McKinsey Report championed the quest for carbon neutrality; creating a circular economy where everything is reused would contribute to this goal. While there is a powerful push globally to reduce carbon footprints, it makes particular sense for New Zealand to focus on sustainability as we are so dependent on our natural environment.

Science and technology is crucial to achieving this aim. Some of our companies have already started converting waste materials into new products. New Zealand Pharmaceuticals turns animal bile into pharmaceutical intermediates and medical diagnostic devices, and Lanzatech creates low-carbon chemicals and fuels from industrial waste.

"If our kids are going to live well, we need to get carbon neutral."

Transport and industrial plants are both good areas for focus in terms of carbon reduction, but the low hanging fruit really is farming. It was noted that we need to reduce carbon emissions of ruminant animals by 40% to meet our international commitments to cut greenhouse gases. Further, we have a growing pollution problem in waterways, which is linked to this country's biggest economic driver (primary production), making solutions difficult. Given this country's expertise in food production, it might make sense to focus on alternative processes for growing plant-based proteins. Trees may provide the answer, for example, pine needles contain high levels of sugar. Of course, how this might fit within the SfTI Science Challenge is unclear.

Renewable energy, energy storage and micro-grids, could also be an area of focus, not least because of the expertise already evident in this country, at Canterbury University for example.

Reducing current pollution levels and achieving real sustainability will take time, and it was considered that taking a multi-generational approach would be vital.

"From an indigenous perspective, we need to think with a 1000 year vision otherwise it's just Business as Usual."

MĀTAURANGA MĀORI AS A GUIDING FOUNDATION

It is important to reference Mātauranga Māori in determining the ethics and values we bring to creating and applying science. Ideally, we will think about how Vision Mātauranga (VM) crosses over into everything we are doing within the Challenge in order to develop a spectrum of different ways to integrate VM into our research.

Mātauranga Māori is not an old knowledge system that has died; it is constantly evolving over time. This vast expertise, built up across generations, is something unique that New Zealand has to offer the world. Further, involvement of rangatahi (young people) is essential because they will take this body of knowledge into the future, building on it in their own ways. A question we must always be asking ourselves is: How can Mātauranga Māori inform and improve what we are doing?

Mātauranga Māori can give the rudder, the compass, the values and principles, and the guiding light for how we might orient the whole process."

There are a number of positive implications of genuinely integrating Mātauranga Māori into SfTI:

- A new approach to timeframes can usefully be employed that draws on the past (leveraging the foundation that has already been built before us in terms of whakapapa, for example), the present (understanding what we need to do now), and future (building foundations for the next generation).
- Data is not currently enabling Māori and iwi to reflect lived reality, and similarly, it is seldom applied in ways that are responsive to or give effect to foundational Māori philosophies such as kaitiakitanga. So what is the lens that can be put over the data, and how might we ensure that the development of algorithms, for example, is impacted by Māori values?
- A Māori approach to communication, and storytelling in particular, has special qualities and impacts that mainstream could learn from. This could be applied to how research teams work together, how methodology is developed, and even how particular technologies such as VR are used.

"We want to link space with what's going on underground from a thousand years ago to a thousand years in the future."

HEALTH & WELLBEING

New Zealand's much-discussed housing crisis no doubt turned Mission Lab participants' minds to the question of how science and technology can help New Zealanders live healthier, more secure lives. In a quest to create more resilient communities, iwi around the country are already investigating new developments in building materials and renewable energy, for example, with an understanding that values and technology must be merged in interesting new ways in order to achieve better outcomes.

Housing

Residential building in New Zealand is essentially a craft, where many small firms build a limited number of detached houses each year for individual customers. But it is time to think of this part of the economy as an industry that can benefit hugely from incorporating new science. Given the government's recent commitment to building 100,000 affordable, quality homes over the next decade, the question was asked about whether there is a role for Kiwibuild in supporting innovation. For example, construction has a long way to go in terms of lean manufacturing and is ripe for new tech to feed into that; how can large scale contract certainty encourage improvements here?

We already have a level of expertise in affordable construction through Framecad, which manufactures lower cost steel frames. The company is currently working with the NZ Product Accelerator to develop technology to replace tents used by aid agencies for emergency shelter. But what else can be done in terms of lowering costs, and what can we learn from overseas?

How do we better incorporate sensors into buildings? Could a ZOZOSUIT for houses be created? How can unhealthy behaviour such as P smoking in rental homes be monitored more easily? And can technology be used to mitigate the resulting poison to keep residents safe? What new materials should we be developing to support technologically advanced housing? Could New Zealand's super yacht industry contribute?

Health

The population is aging in New Zealand and around the developed world, with people being encouraged to stay in their own homes for longer. In-home healthcare robots are already being developed for the elderly. They can measure vital signs such as blood pressure, and remind patients when to take medication. Age-related health problems are expected to be at such a scale by 2050 that human caregivers simply will not be able to cope, making technological help essential. There is potential for AI and VR to provide social interactions via robots too.

Personalised nutrition is on the rise in the West; it is already becoming commonplace in some Asian countries where food has long been valued for its functional health benefits. Comvita has been actively researching functional foods for some time, and enjoying good commercial success in China as a result. As a growing trend, personalised nutrition will soon begin impacting consumer choices so New Zealand needs to be at the centre of developments; continuing to sell bulk commodity foods is not the pathway to capturing this opportunity. Growing food in controlled environments may well be part of the production process of meeting consumers' specific nutrition needs. Finally, personalised nutrition could fit nicely into the Māori economy as an example of kaitiakitanga.

"We want to grow a forest of food not a forest of pine trees because there's benefit to our communities in that as well as benefits to the economy."

Wider infrastructure

There appears to be a push for greater urban intensification, which comes with its own set of challenges, while those living in rural communities often have to cope with poor access to the internet, education, and transport. How can infrastructure in both densely and sparsely populated parts of the country be improved to make life better?

When people live together in urban environments, sanitation is a key expense. What if technology could be used to replace large scale sewerage pipes with small, highly flexible ones connected to individual houses. Each house could have its own maceration plant that communicates with neighbouring plants to take turns in expelling waste to a collection point.

Efficient use of energy was raised several times during the Mission Lab. Solar energy is becoming cheaper, but the real challenge is how we might reimagine and reorganise the electricity reticulation system so that excess energy can be shared within communities. While regulatory restrictions are noted as a barrier, science and technology also have a role to play in terms of developing a nanoscale grid, or improving battery performance, for example.

SUPPORTING TOP TALENT (ENTREPRENEURS, SCIENTISTS, AND TEAMS)

Greg Cross, a well-known serial tech entrepreneur, spoke for half an hour on what he had learned throughout his successful career. A key message was that valuable tech companies emerge from deep expertise and research in niche areas. For example, Mark Sagar is the world expert in animating faces – the basis for Soul Machines; John Boys was the world expert in wireless charging – the foundational tech for PowerbyProxi.

Attendees acknowledged that many of New Zealand's great inventions and businesses have come out of one person's garage rather than from a strategic programme of work. Hence the importance of recognising and celebrating these passionate people when we can because they drive innovation. The question was asked: How can we create a system that helps these leaders to do their work?

"Unless our research is the best of the best in a rapidly changing world, it won't be successful."

Equally though, in taking a longer term view, participants were keen to ensure that good work could be extended and leveraged beyond individuals to achieve maximum benefits. How do we build a platform or ecosystem from which others can build businesses? Top world experts can attract the best talent from around the globe to work in their teams. The importance of teams cannot be understated given that technology is becoming increasingly integrated across categories. One of SfTI's underlying principles is to form best New Zealand teams, so the Challenge is already heading in this direction.

INTEGRATION OF STRUCTURES AND PROCESSES

The Challenge is already taking a leadership approach to internal capacity building, but there are external structures and processes that will impact on the programme's overall success. It was thought by some attendees that 'science and technology' is not the hard part; it's about stitching things together to bring benefits to the world. For example, the ability to combine underground sensor and satellite information means we have huge amounts of data, and we could utilise VR or IoT to create new applications … but we need to first think about how we can make better decisions for New Zealand that make sense now and within a 1000 year timeframe.

Particular integration issues include the government's role, the need for a multi-disciplinary approach, how Māori are genuinely engaged within science, and how industry and researchers can better connect.

Government

Government has a huge role in enabling science and technology to support economic growth and wellbeing. The GovTech sector is worth around $460 billion globally, with New Zealand being a leader in this space together with Singapore and Estonia. We are well placed to create a joined up ecosystem that lets tech thrive to assist in clear decision-making to solve this country's big problems. For example, how can we easily access data from various government entities and combine it in ways that make the best use of tech and leads to best outcomes?

Policy and legislation are crucial here. Examples were shared during the Mission Lab of the structural and legal impediments that stand in the way of streamlining our healthcare system. Similar barriers are presented to those wanting to create better energy systems.

Investment is another area where the government can help support innovation (or not). The opportunity for New Zealand to develop new science and technology to solve our housing problems was noted. Having a big customer is a key factor in innovation companies surviving, so how the government spends its housing budget over the coming years will either feed or starve clever ideas.

Multi-disciplined

Lanzatech is an interesting example of how bringing new realms of expertise to an old problem can lead to clever innovation. The founders aimed to create usable energy from industrial waste – as had many others before them – but they came to the problem as biologists, and this was the novel approach that spawned a successful company. As technology becomes increasingly integrated, multi-disciplinary research teams would appear to be vital to fully identify the best opportunities, and to capitalise on them. We need to be better at getting the right people around the table to explore and decide how we are going to address problems; the right people might include scientists, entrepreneurs, iwi and government representatives.

The need to work across disciplines suits New Zealand as our small size means people have to work across industries and topics. Most of us are generalists, but potentially, with a stronger team-forming ethos, people could become freer to develop the deep expertise in niche zones considered so important for creating world-leading tech.

Involving Māori

Genuine engagement of Māori is an issue noted across a number of forums including the Mission Lab. Sometimes scientists contact Māori just to satisfy an official Vision Mātauranga requirement late in the proposal process once a research idea is already decided, however, failure to engage early in the process means meaningful Māori input is difficult.

There are a few examples of genuine partnership where Māori knowledge is combined with Western science. Work in the natural environment, particularly waterways, has identified opportunities to align values and goals, to enable mutual learning, and to support a range of diverse people being able to work together to solve problems, including iwi, councils, CRIs and universities.

"There is the opportunity now for scientific data and cultural data to sit right alongside one another, not to say one's more important than the other or means more or less, but they have an equal place in the world."

Connecting Science and Industry

Despite the New Zealand government spending around $1.6 billion on science and innovation, we are still seeing relatively low rates of successful commercialisation, and the full potential of IP is not being maximised. Industry and the research sector are not well enough connected to bring science to the customer. As one industry participant noted, "The science ecosystem in New Zealand is noisy. We have 11 National Science Challenges as well as CRIs and universities – it's a nightmare for businesses."

NEW ZEALAND PROBLEMS

Key questions we must ask ourselves are: What would move us from where we are now to where we want to be? What are the challenges in this country that if solved, would be really beneficial? Part of finding these answers is thinking in the first instance about our problems, and only then considering the science and technology. The important tech for this country will be that which solves uniquely or primarily New Zealand problems.

Mission Lab participants agreed we should focus on where we already have good knowledge, for example, growing food, albeit in different ways that embrace new technological developments. As smart people have been saying for some time now, what has given us competitive advantage during the past decades, that is, commodity food, will not serve us moving forward. One sector we need to quickly transfer our expertise into is foodtech.

Finally, group discussions kept returning to our country as a living laboratory - part of a 2000 year old experiment. Our resources are the land and water, sunshine, nutrients, people, culture, biodiversity, and knowledge (from the past, today, and for the future). New Zealand can and should be guided by the science and problems already in evidence, and we have the perfect environment in which to trial new innovations.

VR/AR

Virtual reality (VR) and augmented reality (AR) received a great deal of attention during the day's discussions (although satellites were a close second). This tool will soon touch almost every industry and be part of the solution for a long list of problems. Other technologies such as IoT, GIS/GNS and AI will soon be working through this medium, and it will be the primary delivery channel for marketing and communications, visual information, and education. It may well provide the very interface we use to interact with the physical world.

It may only be 5-10 years before the rule of screens is over and we all have AR Glasses. Magic Leap, for example, may release a developer's kit next year.

"Whatever we're working on today, VR will probably be the way we communicate it in the future."

Given its future ubiquity, purposeful regulation by New Zealand will be vital lest large multinationals such as Google take control of the virtual digital space. For example, it will likely become common for Glasses to overlay visual and audio stimuli onto the natural world for purposes such as advertising. How do we allow organisations to communicate through AR in ways that fit with accepted values?

In terms of opportunities, the user journey or user experience is of great interest because regardless of the message or channel, the human factor will still exist as it does now. When it comes to VR, AR, and mixed reality, storytelling is a key use. How do we encourage people to emotionally connect through this platform? How do we design communication through this platform for all the things we want to achieve? And how do we integrate AI or IoT to ensure the applications being built have real relevance to how people want to live their lives?

SECTION 5:
IDEAS FOR SPEARHEAD PROJECTS

Six mission-led big ideas for the next stage of this National Science Challenge were explored, raising a number of questions to be answered as they are further developed by researchers and industry experts to form targeted Spearhead Research projects that align with SfTI's purpose. This next round of Spearheads will begin in mid-2019.

The Spearhead directions:

- Place-based Awareness
- Space and Spatial
- Smart Houses
- Veracity – the Truthfulness of Data
- Biosecurity
- Soft Electronics

The threading of Mātauranga Māori through these ideas, and potential for Māori led projects arising from the Mission Lab, are also summarised.

PLACE-BASED AWARENESS

– how do you bring together AR, IoT and all the other technologies to create real awareness about a place, what's going on there, how that place is performing, and how systems (human and technological) are working?

The Vision:

Very soon there will be a massive amount of data available, and it will potentially be available via AR. We need to create a system that intuitively understands what information people need and then delivers it to them. It would be contextually aware presentation of data that may be static information for reference, or real time during an unfolding event.

We might call it: Contextually Aware Reality (CAR) or Contextually Aware Dynamic Data Presentation.

The Problem/Opportunity:

Currently there are no single platforms or networks where organisations can distribute - and people can access - all the data that could be utilised at any given moment. We have to actively seek out information, and even then, are unlikely to access everything we want. Part of this issue is that essential data tends to be held by discrete organisations. The solution is not simply having a person ask for the information they want because they don't always know what is available or what information they need at a particular time or place.

The New Zealand Connection:

To an extent, this may not be considered a New Zealand-specific problem. However, given the inexorable move into the online world (virtual realities are beginning to take us there in a very visceral way), we need to own our digital space. We cannot rely on Google to solve this problem for us, not least because it does not hold our values. Our key task in preparing for the future digital landscape is to ensure we make the transition towards receiving the right data at the right time, as opposed to simply seeking and filtering information as we do now or becoming the passive recipients of whatever stimuli others think we should be exposed to. We must identify for ourselves how we manage data sovereignty in a way that is appropriate for Aotearoa-New Zealand.

Applications:

Citizens could help solve environmental and social problems if they had better access to real-time and infrastructure data. Equally, those tasked with supporting and protecting the populace could be enabled by contextually aware data. A number of potential applications are immediately obvious:

- Health: Currently the medical system is under immense pressure, so we should be exploring what educational awareness and information could be shared to help keep people out of hospitals and clinics. It could be as simple as CAR noticing a mole that needs to be checked by a doctor, or telling occupants to open windows when their home becomes damp.
- City Infrastructure: There is a great opportunity for citizens to modify their behaviour in ways that make communities safer, healthier and more efficient. For example, Auckland Council's Safeswim website, while very simple in terms of the technology, has created a high level of community awareness of what is happening in near real-time on their beaches, which allows people to respond based on knowledge. The question must be asked: "What are the million other things we want communities to know to help them be safer, and make good decisions for themselves?"
- Public Safety: Tracking crowd behaviour during events to quickly identify risks and apply mitigation strategies could pre-empt disasters. Equally, during already unfolding emergencies, first responders could more quickly asses a situation in order to determine best actions and additional resource needs, while citizens could be informed via their devices how to stay as safe as possible and how to co-operate with authorities.
- Digital Persona: If each of us had our own personal AI from birth, it could hold all personal information, and operate in the digital world on our behalf, thereby promoting equal opportunity.
- Content: Currently there is not a great deal of content to feed into a VR world, but there will be content in 50 years' time. How will we manage the overwhelming options, and how will we choose the applications we want to access? There may be the opportunity for aggregation apps that manage a suite of other apps, for example.

The Science and Technology:

- Data needs to be brought in from many sources, including government, councils, universities, satellites etc., probably using APIs. Some datasets are hard to deal with, and may have restricted or aggregated access (probably about 20%), but the rest would be publicly available.
- It is important that a significant proportion of the data is real-time or near real-time. Citizen science can feed into this, as well as drones, satellites and sensors. This should definitely stretch beyond static/historical databases.
- Layering of information is an important consideration.
- What are the privacy implications? This is why it is so important for us to own our own data.
- Rather than one big database holding all the data, it would be important to create a federated model where data is stored in many different places with trusted protocols for accessing that data. No single person or entity would be the owner. This is probably a legal question as much as a science one. What are the levels involved, the controls put in place, and the processes to be used in order to create this distributed system?

Questions for Further Development:

- To what extent might the idea of controlling data sovereignty for VR duplicate work being done under the Ātea Spearhead?
- What is the new science here to be explored?
- Which issues are about deployment, policy, integration and scale, rather than new science? Who is responsible for these other aspects and would they be partners for the novel research aspects? For example is the NZ data commons project relevant?

SPACE AND SPATIAL

– how can we support and capitalise on nascent space technology to advance potential benefits for New Zealand?

Photo: RocketLab

Vision:

New Zealand's fledgling satellite sector continues to grow, with a whole ecosystem developed to support and learn from the activities of RocketLab (and potentially other similar companies). As our space expertise grows, we integrate the most accurate earth observation data with other pieces of science and cultural data to support activities on the ground. Application targets might include productive environments, natural environments, and managing human behaviour.

The Problem/Opportunity:

Rocketlab's success means New Zealand is one of only ten countries in the world that launches rockets. There is a great deal of science around sending objects into space and getting them back down again. The opportunity is to increase our expertise in the science of space travel, including: achieving orbit, space craft construction, geoinformatics and the ground segment. Further, the ability to develop new applications for supporting human activities on land and sea presents further opportunity.

The New Zealand Connection:

We are already world leaders in GPS and GIS technology as evidenced by companies such as EROAD and Cortex, which control a significant portion of the US trucking sector. As already noted, RocketLab provides the opportunity to drive the creation of a whole support industry.

Applying space tech to primary production is particularly important for New Zealand given it is a significant foundation for both the Māori and non-Māori economies.

Applications:

The primary sector is an obvious beneficiary of earth observation satellite data, particularly for improving precision, and allowing remote monitoring. This is about increasing yields and efficiencies, and it is acknowledged that there is already some reasonably advanced technology in this area. For on-farm/forest decision-making, real-time or near real-time data is important. How might the health of commercial forests benefit from closer monitoring of plant and soil health? Providing guidance on optimal harvest timing would be a real boon to forestry managers. Further, mapping topography could be used in planning forestry roads and harvesting activities. While LIDAR is used to map bare earth in large forestry operations, it is not economic for small business. Does satellite data have a role to play in providing a more affordable mapping solution for managing small holdings?

Monitoring the natural environment is seen as a key use for space technology, although more thinking is required in terms of what should be tracked and measured. New Zealand is well known for its Clean, Green marketing, however, it has also become obvious there is a disconnect between the message and the reality. We need to do better in protecting and preserving our forests, waterways, air, beaches and ocean.

An important consideration is how satellite data might be layered with data from other sources, and even exploring new methodologies. For example, how might earth observation data meet VR to help tell the story of New Zealand's natural environment and help persuade people to act differently? Could drones be used for collecting atmospheric data, passively monitoring particular areas and only communicating data of interest? Could predictive models be created to stop the spread of disease such as kauri dieback. How might weed and pest management be supported?

Currently, governments around the world are trying to solve the problem of antisocial behaviour using people-oriented science, however, perhaps physical sciences and technology have something more to offer. The growing prison population, which is a worldwide problem, might be positively impacted by applying the progressive removal of personal freedom (digital control) depending on an offender's actions, as opposed to the more binary approach of either incarceration or non-custodial monitoring (i.e. electronic bracelet). Further, could some kind of stimulus be applied to individuals to stop unlawful acts? Could swarm technology be used for search and rescue with drone to drone connectivity? And how might drone-satellite partnerships assist with monitoring EEZ border incursions or controlling crowds?

The Science and Technology:

- Developments in optical, hyper spectral, multi-spectral, and synthetic aperture radar.
- Automation and flying beyond line of site – this is where there is still plenty of work to do.
- Real time data and connectivity.
- Cloud cover opacity at different frequencies.
- How can we bring down the size of satellites? And how can we better utilise cube sats?
- Data fusion – optical, hyperspectral and multispectral.

Questions for Further Development:

- Given that a number of the ideas discussed may constitute integration rather than novelty, what is the new science here?
- What is the crossover with other NSCs, particularly Our Land and Water?
- What is the crossover with existing SfTI projects, namely 'Visual Recommender Technology for Exploratory Analytics: Predicting Forests Futures', 'Deployable Nano-Satellite Synthetic Aperture Radar for Monitoring NZ's EEZ', and 'Landscape-scale Augmented Reality: Enhancing Public Understanding of our Cultural Heritage'?
- There needs to be a stocktake on current research work and industry investment.
- Which new technologies promise the most significant potential economic benefits?

A NEW VERSION OF SMARTHOUSES

… ZOZOSUIT for houses. It's about understanding where the technology opportunity is to really understand and augment housing.

Vision:

Being able to manage infrastructure is a key challenge for city planners around the world, and it's only becoming more complicated. Often factors such as logistics and transport, or energy efficiency are the focus … but what about improving a city to make it a fantastic place to live to attract the best talent? How can we make rural areas similarly great places to live for those who want to live there?

What if the houses had sensors that could be used throughout the building process to ensure plans are followed and verified materials are used. And then when it is 'live' with occupants, the technology would know the people inside, including their health conditions, so recommendations could be made for living healthier. The house would also be linked to the community and wider infrastructure with two-way information sharing. And what if affordability was a key criteria for success?

The Problem/Opportunity:

Several interlinked issues would benefit from work in this potential research direction. First, housing has become increasingly unaffordable, particularly in New Zealand's main centres, meaning home ownership is difficult for many; renting does not come with certainty and some properties are in less than ideal condition. Second, the population is ageing and government policy encourages the elderly to stay in their own homes for as long as possible. How can technology keep older people engaged and connected with the wider community? And third, increasing environmental degradation requires action on multiple fronts; housing-related pollution from building materials and sewerage, for example, could be mitigated using technology.

The New Zealand Connection:

What is unique about New Zealand is the potential at the current time for a large building programme by government to try new things related to tech-enabled healthy homes. A large scale program could be integrated into long term planning. If the government decides to invest in good technology such as sensors, insulation and communications, innovation will be encouraged, and the price of this type of home could be reduced. This is an ecosystem opportunity.

Applications:

- Building homes at the centre of a layered structure, a goal that iwi around the country are already turning their attention to – they would connect with surrounding homes and community, and in turn connect with the wider city infrastructure. Two-way information sharing is key to creating benefits above and beyond the disconnected, analogue way neighbourhoods are currently built. In this way, Smart Houses become part of Smart Communities.
- Buildings that keep owners/managers up to date with required maintenance.
- Systems for feeding back real-time information to city planners to help them create more efficient and liveable infrastructure.
- Provide those in state housing with advice on how to live within their home as if it were their own, for example, when to open windows.
- Bring personal nutrition into the home and make it easily utilised.

The Science and Technology

- Perhaps one of the key challenges for any of this science is to create the technology without increasing the cost of building.
- Developing new building materials. One theme could be to use waste from other systems/industries. Another might be homes that will not catch fire.

Questions for Further Development:

- Given that a number of the ideas discussed may constitute integration rather than novelty, what is the new science here?
- What is the crossover with other NSCs, particularly Building Better Homes, Towns and Cities, and which parts are complementary new technologies that align with SfTI?
- There needs to be a stocktake on current research work and industry investment.

VERACITY

– truthfulness of the data, the place, the people … what is the technology that sits behind proving we are delivering on our claims?

Vision:

How do we manage distrust? How do we remove source impurity and collusion opportunities? How do we verify veracity? Ultimately, it is about giving consumers confidence in our products and in our country.

The Problem/Opportunity:

The 'story' of our place has to align with truth – this is becoming more and more important just as people become less trusting of digitally-sourced information. Place of origin will become more influential in consumer decisions making stories more important than ever.

The New Zealand Connection:

Our isolation is our strength (protection) but at the same time, distance from our customers is a disadvantage because we have to create trust remotely. To date we have relied on trust in our brands and NZ Inc., however, this is a risky strategy as reputations can be ruined in an instant.

Applications:

- Creating compelling information with provable veracity about New Zealand as a destination for the world's best innovators and entrepreneurs so they relocate here.
- Mini smart contracts along the supply chain using blockchain and managed by independent parties. Does this tech already exist, and can it power provenance or a veracity concept?
- Proving provenance of food exports.

The Science and Technology:

It is acknowledged that there is a great deal of work already taking place in this area, particularly with the application of blockchain technology to supply chains, as well as biological testing of food, for example. However, just as the technology has moved on, so has the question. For example, in the face of greater pollution, consumers are demanding finer details about their food. Country of origin, while still important, will soon not be sufficient; people may want to know what their dinner fish ate, details of its DNA, or even migration patterns to check for exposure to areas of radiation. How can so much detailed information be linked to a single food item?

Additionally, the question remains as to how much integration of existing technology is required, and what novel science is still to be uncovered?

There may be an opportunity for forensic science, isotope chemistry, DNA technologies and/or social science, to be added into the mix through being overlaid onto technology platforms already in existence in a way that allows us to examine (and perhaps control) motivations, behaviours and biases to arrive at a true veracity.

Questions for Further Development:

- Given that a number of the ideas discussed may constitute integration rather than novelty, what is the new science here?
- What is the crossover with other SfTI projects, namely 'PVC – The Science of Trust'?

BIOSECURITY

– using science and tech to help us achieve much greater progress on biosecurity.

Vision:

To be able to identify biohazardous incursions before they arrive in New Zealand in order to keep them out, and to find solutions to bio-problems we already have. Further, it would be highly beneficial to educate and persuade the public about the importance of biosecurity.

The Problem/Opportunity:

There is some suggestion that with climate change (particularly the warming atmosphere and sea) pathogens that were once restricted to small geographies are now spreading throughout the world. Given this country's reliance on exporting food, using tech to enhance biosecurity capability constitutes smart economic risk reduction.

The New Zealand Connection:

Biosecurity 2025 is about to launch, with a science plan currently being developed; SfTI has the opportunity to contribute to this given that engineering is an important element of the strategy. DNA technology could be used with sensors to obtain instantaneous results, for example.

A recently publicised biosecurity breach was Myrtle Rust. The fungus has serious consequences not just for Pōhutukawa trees (and other myrtles), but also for the soil beneath their feet which they help stabilise. Improving our response to these threats has multiple benefits.

Applications:

- Prioritise risks and target planning through cataloguing what pests and pathogens are already in New Zealand, as well as what has not yet arrived.
- Develop a tool to scan boats to identify infection before it reaches our ports.
- Develop predictive response models through understanding how pathogens travel within New Zealand once they arrive.
- Use of connected drones, including spotters and attack drones to kill pests (animals and weeds).
- Develop new traps using metamaterials, for example.
- Use VR to create full emersion experiences of what pest-free New Zealand would actually look like with regenerated forests, and equally, what it would be like if new pests became established. The goal would be to change people's attitudes and behaviours.
- Perhaps using VR to harness the power of all those people who visit New Zealand's natural environment to increase biodiversity. This potentially crowd-sourcing solution still needs to be further explored.

The Science and Technology:

There are some questions about how we might draw from multiple disciplines to really understand and respond to biohazards. For example, with regard to Kauri dieback, have we really done enough to examine the potential solutions that could come out of engineering, Mātauranga Māori or medical science? Is materials science useful? What about bio-inspired engineering such as soft robotics (e.g. robotic insects)?

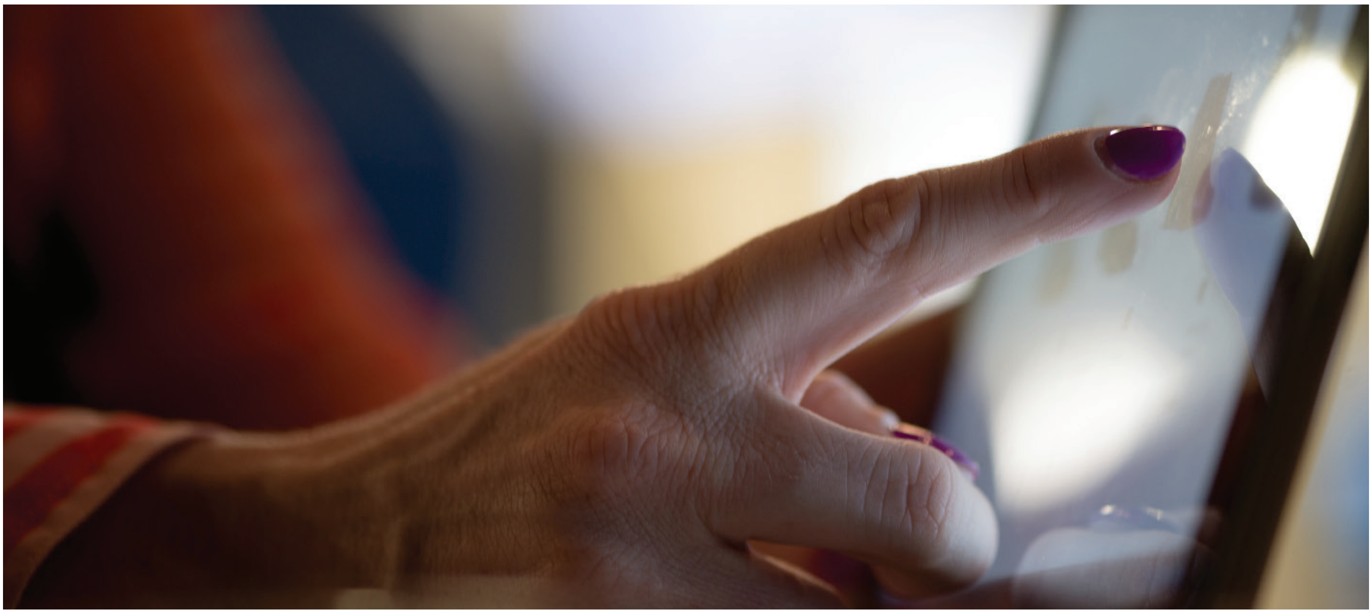
Similarly, when it comes to actioning any solutions, it makes sense to combine biosecurity and customs in terms of sensing drugs, biohazards, and even terrorism. How might we harness games and gamers to capture their imagination and then have them help build responses? New Zealand's many small islands can be testing grounds for new solutions. These kinds of combinations would seem to have good commercial potential.

Questions for Further Development:

- Given that a number of the ideas discussed may constitute integration rather than novelty, what is the new science here?
- What is the crossover with other NSCs, particularly ''New Zealand's Biological Heritage' and 'Our Land and Water''?
- What is the crossover with other government initiatives such as Predator Free New Zealand and Biosecurity 2025? And with other projects such as the Cacophony project?
- There needs to be a stocktake on current research work and industry investment.

SOFT ELECTRONICS

– what is the current state of play and how do we advance the technology? What might be some of the avenues to pursue?



Vision:

Soft electronics is a relatively new area of science and technology, particularly in terms of power generation and stretchability, and its full potential is still being explored.

The Problem/Opportunity:

Electronics are largely built from hard rigid materials, which has advantages (strength and durability) and limitations (they don't bend or stretch). For example, wearable sensors such as the fitbit stay outside the body, can break, and are limited in the amount of data they can sense. However, flexible devices are coming onto the market, while the science of stretchability still has some way to go.

The New Zealand Connection:

While there was little New Zealand-specific discussion related to soft electronics, it was suggested the technology could underpin tools developed for physical rehabilitation and assisting the elderly; this has the potential to reduce New Zealand's annual falls-related bill of $1.2 billion. Given that an ageing population is in evidence across Western countries, there is also potential to create exportable products.

Applications:

- Smart screens, touch pads, and phones that can be stretched to make bigger/smaller.
- Putting the technology into fishing line (making it the sensor) allowing fishers to measure what is going on under the surface.
- Capturing a golf swing movement in order to identify corrections needed.
- Recuperation from illness/operation by helping with rehabilitation movements. Wearable assistance devices to prevent people from falling.
- Artificial, flexible heart.
- Actuators/motors.
- Power generators (though body movement).
- Printable electronics.
- Develop a soft shell for houses made from biopolymer. More thinking is required in terms of the benefits of a soft skin, or even one that could exhibit rigid or flexible characteristics depending on the stimuli applied.

The Science and Technology:

Current electronics are full of components that are mass produced and so are very cheap, while making soft electronics is labour intensive and expensive. An interesting question for researchers is how to achieve commercial scalability for soft components at a reasonable price.

Materials science is an integral element of soft electronics. Rubber polymers are commonly used, as are conductive fabrics, electro active carbon, graphite, and liquid metals. More research into materials would be useful, particularly with regard to bio-materials such as lignin, and silicone which is biocompatible and therefor implantable.

One of the biggest opportunities is to focus on body movement, including asymmetry and gait analysis. This can be applied to athletes, those in rehab, and older people. One project example is the development of a knee brace that would recognise when the knee was in an instability state and when triggered would squeeze a particular part of the leg to help train the person back to walking safely. The human element of utilising soft electronics for health cannot be ignored. For the elderly, compliance is a big challenge. A health robot could be employed to encourage desired behaviours, but this important issue requires social science input.

A further area for focus is sensors. Existing sensors have no intelligence, they simply collect and send data. How might soft electronics enable sensors to interpret information into meaningful insights?

Questions for Further Development:

- Given that a number of the ideas discussed may constitute integration rather than novelty, what is the new science here?
- What is the crossover with other NSCs, particularly ‘Ageing Well’?
- There needs to be a stocktake on current research work and industry investment.
- There is a history of research in bendable electronics; what are the new opportunities and best direction for New Zealand in terms of stretchables?

MĀTAURANGA MĀORI

As discussed, Mātauranga Māori should be threaded through all the concepts to be developed into potential SfTI projects.

The two concepts arising from the Mātauranga Māori discussion were:

- Mātauranga Māori and telling of stories. This is already incorporated in the new Ātea project which is under development, and two current SfTI seed projects. Discussion can continue to explore this area.
- There is potential for development of a new project about the appropriate and beneficial use of data for Māori, including: how it gives effect to foundational Māori philosophies, such as kaitiakitanga, and how we might ensure that the development of algorithms is guided by Māori values. The concept requires further development, and exploration with Māori leaders and Māori business.

SCIENCE FOR TECHNOLOGICAL INNOVATION

Kia kotahi mai –
Te Ao Pūtaiao me
Te Ao Hangarau

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