THE SCIENCE FOR TECHNOLOGICAL INNOVATION (SFTI) CHALLENGE

Kia kotahi mai – Te Ao Pūtaiao me Te Ao Hangarau

Industry-Led Consultation

Summary Report

May 2017

National Science Challenges

SCIENCE FOR TECHNOLOGICAL INNOVATION

Kia kotahi mai – Te Ao Pūtaiao me Te Ao Hangarau

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Introduction

The Science for Technological Innovation (SfTI) National Science Challenge is set to invest in new multimillion-dollar research programmes to support technological innovation for New Zealand enterprise, including the Māori economy. The Challenge is one of 11 National Science Challenges targeting specific goals to bring significant, enduring benefits for New Zealand. Its mission is to enhance this country's capacity to use physical sciences and engineering for economic growth. It involves more than 100 researchers from all New Zealand universities, three crown research institutes and one independent research organisation.

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; this has informed the development of new Spearhead research projects. The ultimate aim is to chart the direction of New Zealand's future high-tech economy.

The current document has been prepared to bring together multiple industry-led discussions and background research. Inside, you'll find basic data about New Zealand's key industries, export activity, markets, and exciting technology trends. Key discussion themes are summarised, and a set of four Spearhead Research directions are described.

What does success look like?

In a word – vision. We're about identifying opportunities, not problem solving or tech-transfer. We've gathered together some truly transformative ideas that involve world-leading science and engineering research that will work for New Zealand.

"Our mission is to enhance New Zealand's capacity to use physical sciences and engineering for economic growth."

Executive Summary

When thinking about New Zealand's place in the global community, and about how we might best position ourselves to thrive in the future, we must pay close attention to what is happening around us. Global uncertainty, politically and economically, is a real issue currently. A new American administration and Britain's vote to exit the European Union both raise questions around the future of our trading relationships. More generally, rising concerns about climate change and the pervasive wealth gap are perhaps changing attitudes of global consumers in a more permanent way.

Despite this potentially difficult context, technology is one area where amazing things are happening. Developments in artificial intelligence, robotics, IoT, and artificial reality are coming together in new and exciting ways. Looking further into the future, cyborg technology, space travel and cellular agriculture will each have differing impacts on this country. New Zealand has the opportunity to decide which of these new directions it wants to dive into deeply.

In order to make these decisions, it is useful to first consider our biggest trading markets, as well as those that represent opportunities for growth. Australia, China, Europe and the US, are important to us now, and ASEAN and India may prove extremely fruitful in the coming years. Further, paying close attention to our assets and how technology can help us create more value should pay dividends. Our existing expertise in the primary industries is noted, as are indigenous knowledge and philosophies.

Industry consultation has revealed key concerns and exciting potentialities on the minds of some of our most successful entrepreneurs. Business is clear about being solution-focused and mindful of multiple outcomes, including social, cultural and environmental. Establishing better researcher-industry connections is also important to those who contributed.

Finally, four Spearhead Project directions have been developed:

1. The Digital Marae/Whare
2. Intelligent Oceans
3. Robots for small scale production and harsh environments
4. Personalised value chain

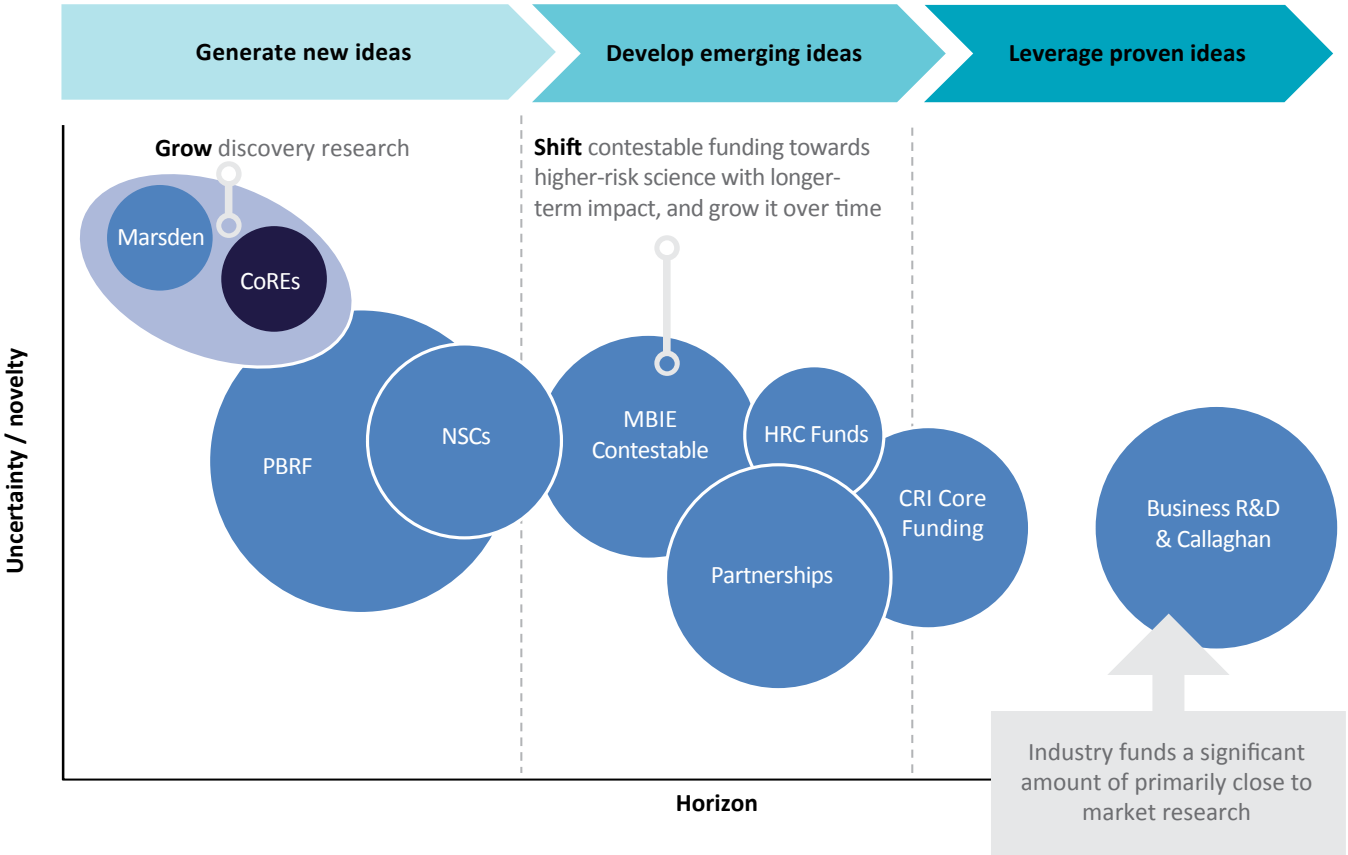
1. The Science for Technological Innovation (SfTI) Challenge

Aims and Goals

The Science for Technological Innovation (SfTI) Challenge, one of 11 National Science Challenges (NSCs), 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 National Science Challenges are tasked with generating innovative new ideas where there is a degree of uncertainty. Ultimately, however, research funded under the initiative aims for excellence and long-term impact.

As the diagram below shows, the NSCs are positioned where new ideas and foundational scientific knowledge are created.



[Source: Partnership Investment Plan 2017-2019. MBIE, November 2016]

The Challenge currently has five portfolios with a 'spearhead' project under each one (see 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.

At least one of the new Spearhead projects will be VM-led, that is, for Māori, by Māori. With this in mind, consultation has included a Māori Business Leaders High-Tech Summit and ICT Hui to discuss what areas of research could contribute to the overall vision of a vibrant and prosperous, technology driven economy.

The mission statement of Vision Mātauranga:

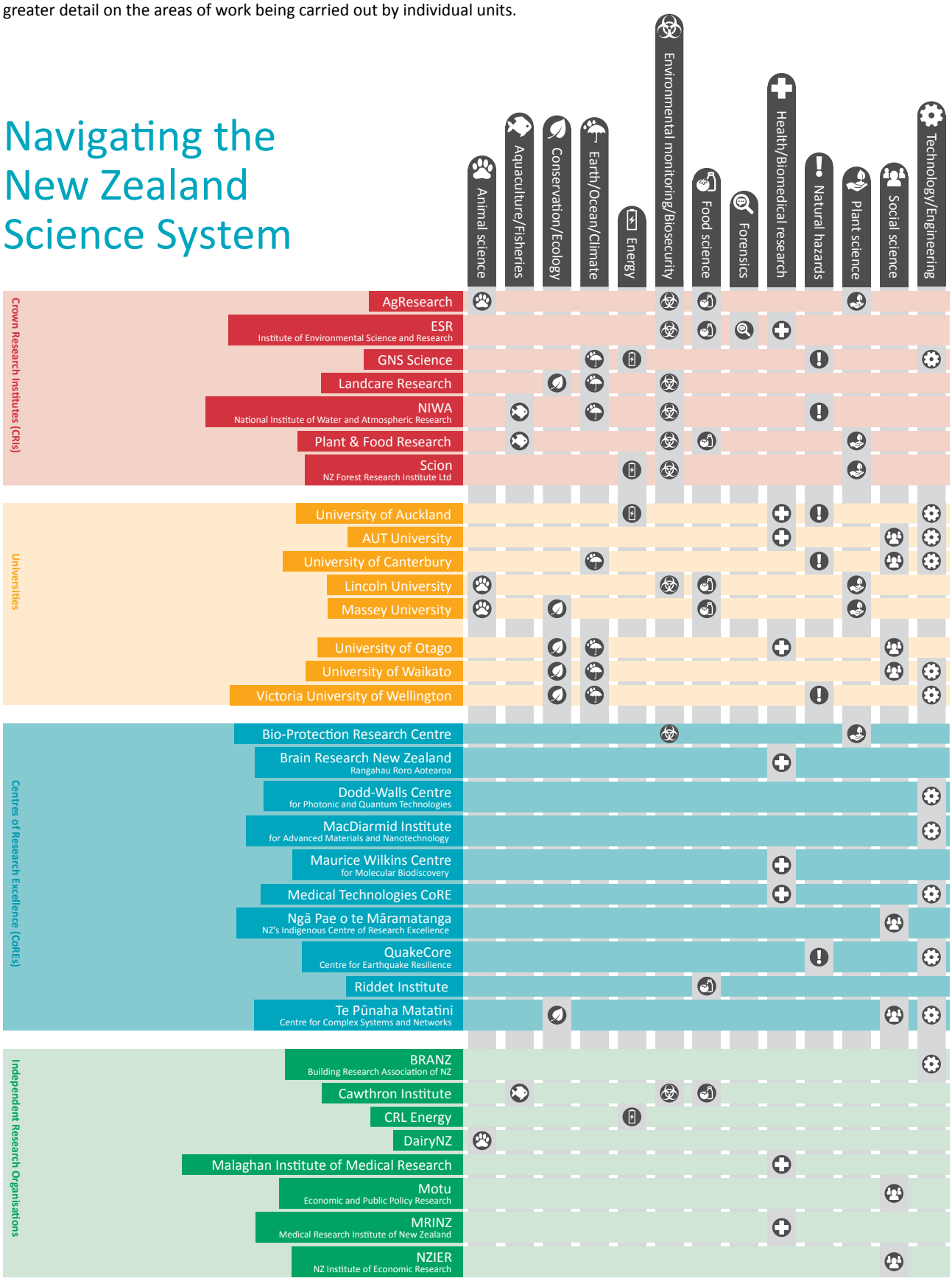
> *To unlock the innovation potential of Mäori knowledge, resources and people to assist New Zealanders to create a better future.*

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.

New Zealand's Science/Research Structure

There are many organisations carrying out research in New Zealand, including universities, Crown Research Institutes and Centres of Research Excellence, as well as Independent Research Institutes and the more diffuse Science Challenges. The table below provides greater detail on the areas of work being carried out by individual units.

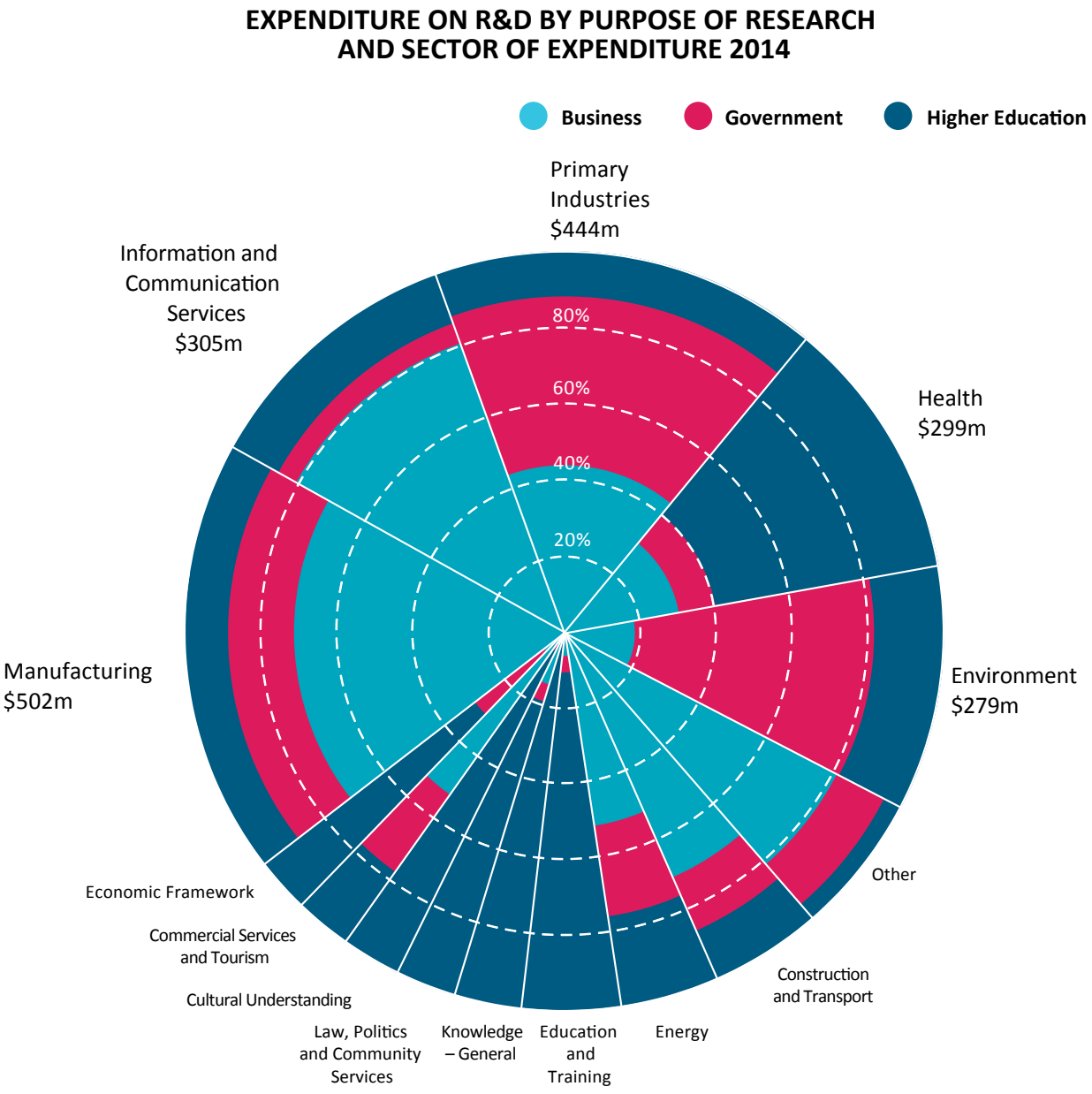


*[**Source**: Desk Guide for Covering Science. Science Media Centre, NZ. **Table Update**: We acknowledge additional work being undertaken within the system that is not listed in the above table, for example, Massey University carries out technology/engineering research.]*

New Zealand's Science and Innovation system is well regarded globally; we are ranked 6th of 163 countries for Science and Technology in The Good Country Index[1]. In terms of academic publishing, New Zealand produces 15.6 papers per million dollars invested, compared with the OECD average of 5.5. The most common areas for publication include agricultural and biological sciences, business, management and accounting, and health.

A separate report has been prepared by Motu in which New Zealand's research activity is analysed.

The diagram below shows where research dollars are currently being allocated and by whom. Primary industries, manufacturing and ICT are the areas of greatest overall investment.



Source: Statistics NZ R&D Survey 2014

1 https://goodcountry.org/index/overall-rankings

2. Global Snapshot

Political and Economic Issues

The apparent rise in nationalism (and protectionism) in response to globalisation will potentially have a big impact on nations that rely heavily on trade, including New Zealand. More detail is provided below.

America's New Administration

There is, of course, great uncertainty in 2017 about America's trading future. Concerns of a trade war with China abound, and the Trump administration has suggested across-the-board tariffs of 10-25%. Subsequent to pulling out of ongoing Trans Pacific Partnership negotiations, the United States government has suggested it is prepared to negotiate trade agreements with individual nations.

Rhetoric about America 'bringing back manufacturing' has been appealing for voters, but in an economy where manufacturing infrastructure and skills have languished in some areas, significant investment will be necessary. The US is already one of the world's largest buyers of robotics for manufacturing so they may be well placed to create a strong high-tech manufacturing base.

Brexit

Britain's mid-2016 referendum on whether or not to leave the European Union resulted in a very small majority voting to go. This will not be a quick transition, however, with the exit likely to take two to three years to finalise. Brexit will not necessarily have a major impact on Britain's free trade ties with the rest of Europe as these relationships are governed by the European Economic Area (EEA) Agreement established in 1994; the outcome is yet to play out.

Climate Change

Issues of climate change, sustainability and emissions, have come to the fore for governments and citizens around the world over recent times. The Paris Agreement, which came into force in November 2016, is the result of the vast majority of nations agreeing to limit global average temperature increases. Crucially, the Agreement focuses on limiting countries' carbon emissions in as short a time as possible.

As extreme weather patterns and temperatures continue, we can expect conscious consumerism to strengthen, with the environmental performance of supplier nations being more carefully scrutinised that it has been in the past.

Growing Wealth Inequality

Overall, the world economy continues to grow slowly (3%) as it has done for the past five years, but with some notably fast growing countries: China and India.

OECD Interim Economic Outlook real GDP growth projections
Year-on year, %

	2016	2017		2018	
		Interim EO projections	Difference from November EO	Interim EO projections	Difference from November EO
World	3.0	3.3	0.0	3.6	0.0
United States	1.6	2.4	0.1	2.8	-0.2
Euro area	1.7	1.6	0.0	1.6	*0.1
Germany	1.8	1.8	0.1	1.7	0.0
France	1.1	1.4	0.1	1.4	-0.2
Italy	1.0	1.0	0.1	1.0	0.0
Japan	1.0	1.2	0.2	0.8	0.0
Canada	1.4	2.4	0.3	2.2	-0.1
United Kingdom	1.8	1.6	0.4	1.0	0.0
China	6.7	6.5	0.1	6.3	0.2
India	7.0	7.3	-0.3	7.7	0.0
Brazil	-3.5	0.0	0.0	1.5	0.3
G20	3.1	3.5	-0.1	3.8	0.0
Rest of the World	2.3	2.7	-0.1	3.2	0.0

[Source: OECD Interim Economic Outlook 7 March 2017, OECD, 2017.]

Poverty has fallen during recent years, but inequality has apparently increased dramatically. It is estimated that half of the world's wealth now sits with 1% of the population, and the divide is widening. Commentators are connecting inequality with a growing distrust of politicians and government systems; the shared benefits once promised by globalisation are being enjoyed primarily by the already wealthy, and as a result free trade is increasingly viewed with suspicion in some nations. What this means for future liberalisation of trade barriers is unknown.

Technology Trends

New technologies and innovation are changing every aspect of human life. Short summaries of where new technologies are currently positioned are included below. While these are listed separately, it is important to note that they are already cross pollinating and over the coming years we will see more and more convergence as different technologies are brought together to produce a seamless experience for users. Technology will become ubiquitous and will seem invisible.

Just as reliable, accessible internet enabled a brand new business model in 'as-a-Service', these developing technologies and applications will themselves create new possibilities for doing business differently. Within this more collaborative ecosystem, high levels of niche expertise may best enable full participation in creating the future and reaping the rewards.

Technologies already being used/commercialised, but yet to be fully integrated into the economy …

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.

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 efficiencies. 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 sales of industrial robots rose to over quarter of a million units in 2015, up from 60,000 in 2009. The global market for robotics is estimated at US$35b for 2015[2] and this is expected to double to 2019.

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.

2 Executive Summary World Robotics 2016 Industrial Robots. International Federation of Robotics, 2016.

IoT and IIoT ... Data Analytics and Sensor Technology

The Internet of Things (IoT) allows realtime 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.

Artificial 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. It's 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.

Early days ...

Evolutionary Leaps

Evolution used to be something that happened to us very slowly and in response to external forces, but humans are now directing our own development in a more purposeful way. Human augmentation and looking to the stars are two ways this is happening.

Cyborg technology goes further than existing medical techniques for implanting devices to correct physical shortcomings caused through illness or accident; this technology is about enhancing basic human capabilities. Currently there is a community of biohackers experimenting with 'insideables' to upgrade their bodies, for example through inserting RFID chips under the skin to allow physical and digital locks to be opened keylessly. Future applications are predicted to include improving memory and controlling external devices with one's mind. Futurist Ray Kurzweil has said that human-cloud connection will be achieved in the 2030s.

Space travel is seen by many as another evolution-focused technology; how can the human species survive as planet earth's resource limits are reached. Multiple technologies are necessary to mitigate foundational problems in this field, from increased propulsion, to radiation protection and lab-based food production. However, given the level of investment being made by some, including SpaceX, one can assume progress will be swift, and commercialisation inevitable.

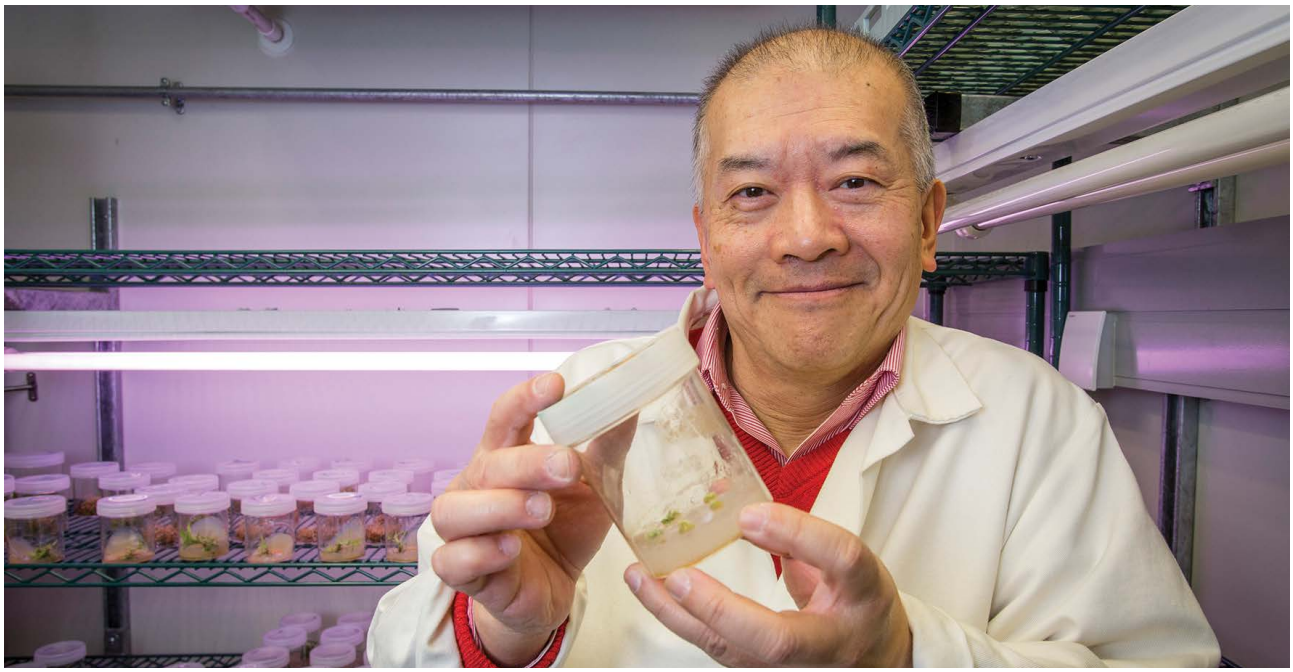
Cellular Agriculture

Cellular agriculture is making huge leaps currently, with numerous startups working to create synthetic foods that are safe, delicious and cheap. Global concerns about the environment have been a key driver of the technology; creating food at the molecular level removes the need for resource-intensive farming practices. It is assumed food that uses significantly less land, water and energy, will become ever more appealing to environmentally conscious consumers. In fact, in a world fast approaching its limits, and with an extra one billion people predicted to move into the middle class by 2030, it is unlikely the earth could satisfy the growing demand for meat, dairy, wine, and even chocolate, using traditional farming methods.

Functional and Metamaterials Materials

Functional materials are the physical building blocks of almost all technology we use today, and developments here will determine what is possible in consumer devices, robotics, energy generation and storage, and even space travel.

Metamaterials are synthetic composites engineered at the microlevel using nanotechnology; the way in which they are created means these materials have abnormal physical properties, particularly in terms of how they interact with wavelengths such as light and sound. The fabled 'invisibility cloak' created at Duke University in 2009 was made of metamaterials that in effect bent light to make an object appear invisible. Developments here are perhaps only limited by the imagination.



New Zealand's Key Markets

New Zealand exports totalled $70.1b for 2016 calendar year[3]. Our primary industries still contribute significantly, but the value of technology and travel are growing: business, personal and education travel ($13.8b), dairy ($11.2b), technology ($6.3b)[4], meat ($5.9b) and logs/wood ($4.1b). Our key markets are Australia, China, the European Union and the United States.

Main Markets

Australia

New Zealand sends its largest share of exports to Australia, and for the year ended December 2016 they totalled $12.9b, down from $14.3b in 2012. Travel services account for 19% of total trans-tasman exports while dairy represents just under 4%.

Our two countries are working towards a Single Economic Market (SEM) that will further enhance two-way trade through lowering trading costs, simplifying transactions, and better coordinating the two regulatory environments.

Australia has experienced its own export woes recently, particularly as a result of China's reduced demand for steel, however, overall the economy remains relatively robust with a growth rate of 2.4%

China

Exports to China were $12.3b in 2016 (up 33% from 2012) and made up primarily of dairy, travel, wood, and meat. Chinese incomes are on the rise and consumers there are keen to spend on foods (including both unprocessed and convenience) and natural health products, as long as they are assured of safety.

New Zealand enjoys a good relationship with China and was one of the first OECD countries to sign a free trade agreement with them. NZTE has identified China's nascent dairy industry as a good opportunity for New Zealand, particularly in terms of selling production and processing technology.

Europe

New Zealand's two-way trade with the European Union in 2016 produced a deficit: exports totalled $8.3b while imports were $11.7b. Our biggest export to the region is travel services, which is worth $2.2b, while meat, fruit and wine account for one third of total export value.

How Brexit will impact trade is still unknown, however, some commentators have suggested that as the UK moves to reorganise its trading relationships, New Zealand may once again become a key partner.

3 Statistics New Zealand

4 Digital Nation New Zealand; From Tech Sector to Digital Nation. NZTech, 2016.

United States

The United States is New Zealand's fourth largest market, with exports for 2016 at $8.1b. At the same time, we import just under this amount resulting in a trade balance of almost zero. New Zealand exports a diverse range of products to the US, with meat accounting for 19%, and dairy just 6.5%.

Nascent Markets

Rest of East Asia

Members of the Association of Southeast Asian Nations (ASEAN) include Indonesia, Malaysia, the Philippines, Singapore, Thailand, Brunei, Cambodia, Laos, Myanmar (Burma), and Vietnam. This group of countries has a total population of around 625 million, and combined GDP is estimated at US$2.8t.

This market, or set of diverse markets, has great potential for New Zealand exporters given its proximity and growing income levels. The ASEAN-Australia-New Zealand Free Trade Agreement (AANZFTA) was signed in 2012 and focuses on lowering tariffs and increasing transparency and certainty between trading nations. New Zealand exports to the region for 2016 were $6.1b, up from $5.2b in 2012. Dairy accounts for around one third of exports.

India

India has one of the fastest growing economies in the world, and its GDP sits at around $2.3t. New Zealand's exports to India totalled $1.8b during the 12 months to December 2016.

As with New Zealand, food production is hugely important to India's economy, in fact, 55% of all employment there is generated by farming and support industries. The size of land parcels tends to be relatively small, with many farms having only one or two cattle, although there are a number of collective-type organisations that help farmers pool resources. There are opportunities to export New Zealand's agricultural IP related to animal husbandry, consumer-level hygiene practices and new seed varietals, as long as we can translate our offerings to India's unique farming ecosystem.

3. New Zealand Snapshot

Demography and Trends[5]

New Zealand has a resident population of 4.7 million. Annual population growth is slow and steady at around 1.5-2%, with both births and net positive migration contributing. In fact, in the year to 30 June 2016, the population increased by almost 100,000, largely as a result of new New Zealanders.

Similar to other developed nations, New Zealand's population is ageing; the average age was 37.1 years in 2016, and this is expected to rise to 40 years in the early 2030s. Twenty percent of the population is aged under 15 years, and 15% are 65 years or older.

Two thirds of the population is of working age, and unemployment rates have typically been at around 5% during the recent past. The workforce is relatively educated with around four out of five people having some formal qualification[6]. It is generally accepted that there is a shortage of skilled technology talent, and women in particular are poorly represented in STEM-related industries and education.

In terms of ethnicity, diversity is growing, most especially in Auckland.

Ethnicity	% of total population	% increase since 2006	Median age (2013)
European	74	14	41
Māori	15	6	23.9
Asian	12	33	30.6
Pasifica	7	11	22.1

Our GDP was $52,953 per person (a total of $241b) in 2015, putting us in the lower half of OECD countries. The gap between rich and poor is relatively high in this country, however, wealth inequality is at a 30-year high in most OECD nations[7].

5 Statistics New Zealand.

6 This includes secondary school qualifications from NCEA Level 1 (and equivalent).

7 Focus on Inequality and Growth, December 2014. OECD, Directorate for Employment, Labour and Social Affairs.

Sectors

This section introduces important components of New Zealand's economy.

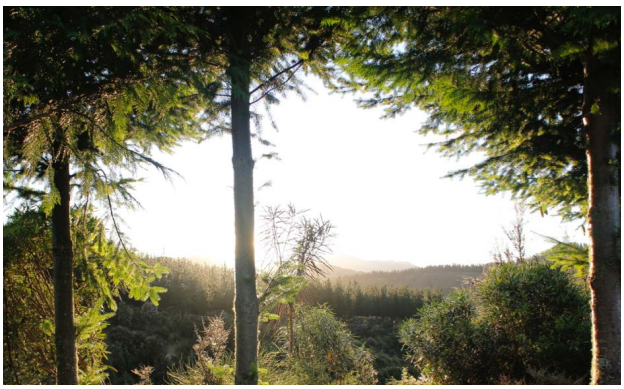
Agriculture and Horticulture

Agriculture accounts for the bulk of New Zealand's GDP and export earnings, and nearly 42% of land in this country is used for agriculture and horticulture[8]. The rate of productivity growth in this sector, while still higher than the global average, is declining, despite recent increases in intensive farming practices.

Dairy production has been steadily increasing across the globe, and this has negatively impacted commodity prices. At the same time, precision farming is coming to the fore around the world: IoT is connecting sensors and devices to enable targeted data analytics which then inform farming decisions. Myriad new startups in New Zealand and overseas are bringing useful technologies directly to the farm gate.

Forestry

There are around 1.7 million hectares of commercial forestry in New Zealand, with radiata pine making up around 90% of the standing volume of half a billion cubic metres. In terms of export earnings, logs and wood contributed $4.1b, and wood pulp and waste paper brought in just under $700m.



A recent New Zealand innovation for harvesting logs from steep slopes is gaining international attention, not least because it increases productivity 20-40%, and significantly lowers safety risks for staff.

Technology

According to NZTech's Digital Nation Report, tech firms now contribute $16.2b to New Zealand's GDP, and earn $6.3b in exports. It's a sector experiencing solid revenue growth of 12%[9]. High-tech manufacturing continues to dominate, accounting for almost twice the total earnings of ICT companies. However, the latter grew around 17% in the 2016 financial year compared with 9.6% for high-tech manufacturing.

A key element of New Zealand's maturing technology ecosystem is a growing emphasis on how technology can support all other sectors of the economy. It is estimated that over the next five years, if businesses make better use of internet services, $34b could be added to GDP[10].

8 Environment Aotearoa; Data to 2013. Ministry for the Environment, 2015.

9 TIN100 Report 2016, based on largest 200 NZ technology companies by annual revenue.

10 Digital Nation New Zealand; From Tech Sector to Digital Nation. NZTech, 2016.

The Māori Economy

The primary sector features heavily within the Māori economy. In total, Māori own around 1.5 million hectares of New Zealand land[11]. Assets included under the Māori economy were estimated at $42.6b in 2013[12], which accounts for 6.1% of New Zealand's total asset base. Around 30% of this sits with Māori collectives, and the remaining with employers and the self employed.

In 2013, the Māori economy generated $11b (5.6%) of New Zealand's total GDP. The primary sector ($1.8b) was the largest contributor, followed by manufacturing and property management (each at $1.3b). These figures highlight the potential to increase the earnings to assets ratio. Adding greater value to commodities derived from farming, forestry and fishing is one way to do this, while promoting Māori philosophies such as kaitiakitanga (guardianship of the land), a world view that is increasingly relevant to global consumers, is another.

Environment

The global shift towards incorporating sustainability targets into economic policy and action is of huge importance to New Zealand. Our economy is highly dependant on the quality of the environment, both in terms of our reliance on agriculture, and the credibility of our global brand.

A report recently commissioned by GLOBE-NZ outlines recommendations for meeting global emissions targets. Net Zero in New Zealand provides several future scenarios with progressively more successful environmental outcomes. Common threads are evident across the scenarios: reducing the number of farming stock and their emissions, planting more trees, and increasing renewable energy generation. Increasing the proportion of electric vehicles is also recommended.

While New Zealand is currently a world leader in renewable electricity, and enjoys a global reputation for being 'clean and green', things are not necessarily so rosy on closer inspection. The OECD's recent Environmental Performance Review of New Zealand highlights this country's over reliance on exploiting natural resources for economic gain; emissions from the agriculture sector are disproportionately high (49% of our greenhouse gas output comes from agriculture) and water pollution is becoming a significant problem.

11 Industry Insights; Maori in the NZ Economy. Westpac Bank, 6 September 2016.

12 Te Ohanga Maori 2013; Maori Economy 2013. Te Puni Kokiri, 2015.

4. Initial Industry Feedback for SfTI

Discussions with nine industry representatives were held during March 2017 to explore ideas around which topics and technical areas the SfTI Challenge should be resourcing to best support New Zealand's future high-tech economy. Additionally, learnings from the Māori Business Leaders' High Tech Summit and ICT Hui have been woven into this section. A forward thinking approach was sought regarding technology support for five to ten years' time.

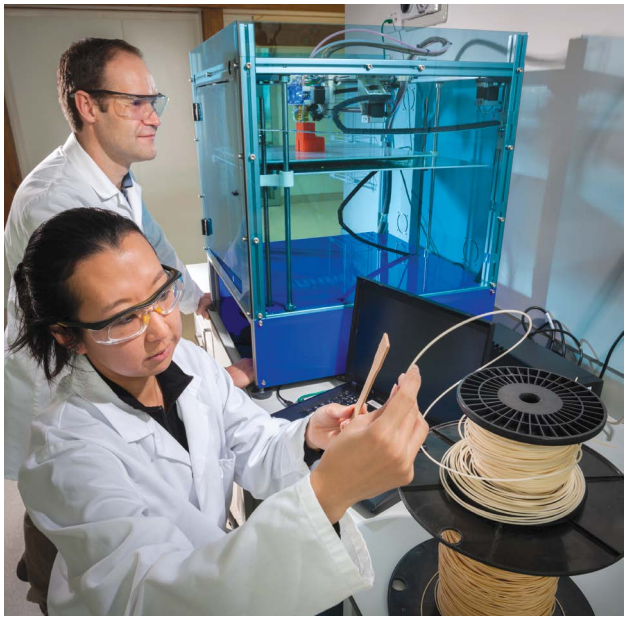
Several key themes emerged that help to focus further discussions on this topic:

We should be aiming as far up the stack of emerging and exponential technology as we can.

Topic areas here include artificial intelligence, automation, machine learning, data flows, blockchain, and VR/AR. There are several rationales for this position:

- these technology trends are inevitable and early adopters put themselves in the best position to thrive
- expertise in these areas can be applied across industries
- expertise in these areas can have multiple applications within any one industry
- government functions can be supported

Competing globally with small, niche, high level IP is a good strategy, particularly when you are physically far away from your markets. Digital technology fits well here.



We should build on what we are already good at.

New Zealand already has special expertise and/or a credible international reputation in several spheres including:

food and functional foods

- we are experts in maximising agricultural productivity
- we are seen as a safe and clean source of foods of all kinds, from low cost milk powder to high value bee products

forestry

- New Zealand is a world leader in forestry harvesting technology

Indigenous knowledge and philosophies

- long-practiced foundational Māori philosophies such as kaitiakitangi and manaakitanga are akin to world views now being expressed by conscious consumers around the world

Additionally, this country already has an extensive agriculture and horticulture infrastructure in place. A significant proportion of Māori assets are land-based and invested in agriculture and forestry, and fishing is an important economic base too.

> *"For Māori to get significant uplift across primary sectors, technology is vital."*
> (Traci Houpapa, FOMA)

Food safety and traceability were mentioned several times as a good area for research focus. Given that global food regulations are strict in our biggest markets (and unlikely to be loosened), it makes sense to be experts. Further, for example, as global dairy production increases, New Zealand may want to move from supplying commodity milk powder to focusing on high value, market-driven products that rely on a good story and proven authenticity.

Whatever we do, we need to start with the problems that need solving.

This is what successful businesses do well – they understand their market and what problems need to be solved for that market. It was suggested repeatedly that the SfTI Challenge could usefully consult with industry/sector groups, as well as with Māori, to better access their expertise on what technological disruptions they foresee, and what problems they need assistance with now and in the coming five to ten years.

A number of people consider that partial responsibility for the under-performance of New Zealand's innovation ecosystem lies at the feet of industry. We have relatively low business expenditure on research and development (BERD) by international standards, and this was variously attributed to: a lack of strategic thinking, leadership with domain rather than innovation expertise, lack of financial resources, lack of science and technology focus, and lifestyle choices. It may be that industry is unable to advise scientists on best research foci.

We should think more holistically and temporally to bring together corporate, social, cultural and environmental, as well as legacy considerations.

There is growing appreciation for the concept of a multifaceted bottom-line within business circles. This is certainly true for Māori business leaders, and is similarly noted by several non-Māori spoken to.

> *"It's important to connect social and business conversations. The heads of strategy, delivery and talent within large corporates I am dealing with see an opportunity to bring social to the heart of their organisations. It's not pervasive at the moment, but the hint of a 'movement' to create purpose-full organisations, is certainly becoming more visible to me."* (Kerry Topp, Datacom)

For Māori, successful economic development is not based on money alone. Instead, the well-being of all tribal members is vital, including through the distribution of wealth and opportunity, and in considering long term consequences. The concept of Mauri is useful here: that which binds us to each other and the world.

Whatever we do, we need to be the best in the world.

In addition to enhancing existing expertise, it is important to ensure other researchers and corporates are not already further advanced in a particular research area.

> *"We would never invest in an area where we have no current knowledge or advantage – then you're just starting at the same place as everyone else, or behind them. That's not a good investment strategy."* (Lewis Gradon, F&P Healthcare)

Those who already have significant internal research capability and/or experience are more likely to go outside of their own organisation only when specialist knowledge and/or equipment is required. When a technology problem arises, tech-savvy businesses are not looking specifically for New Zealand-based expertise, they immediately search out the world expert.

Several people noted that New Zealand should look to find strength in our smallness, in our agility, in the eclectic nature of our population and businesses. Our small size should allow easier cross-sector pollination and co-operation, for example, and there are likely other advantages to exploit.

An interesting issue that arises here is intellectual property. Ownership was a bugbear for many; everyone wants it! Some business people are particularly appreciative of researchers who freely share their knowledge without being sticklers for contracts, especially at early or enquiry stage. For Māori, there is a sense that IP/mātauranga Māori is not sufficiently valued, whether in terms of sharing general advice or more traditional knowledge. Further, IP has direct links to outcomes and consequences – influencing what benefits come from technology may be as important as ownership itself.

Better connections between Researchers and the rest of New Zealand are vital.

A common theme was that there is a disconnect between the research community and business, including the Māori economy. Business wants to know what is currently possible and what this country's areas of research expertise are. Similarly, there is a real desire from business for researchers to better understand them in terms of problems, language and context.

> *"We don't have a common language or agenda."* (Andrew Hamilton, The Icehouse)

The Māori Business Leaders High Tech Summit raised some very specific barriers between Māori and technology research for economic development:

- **Bureaucracy.** Funding applications and business case requirements are onerous, and may not be appropriate or realistic, especially for smaller Māori organisations that already have significant administration costs.
- **Not valuing Mātauranga Māori.** Despite research funding applications containing a small section labelled Vision Mātauranga, non-Māori researchers do not necessarily understand how to engage with and involve Māori (or integrate Māori wisdom) within research.
- **IP.** How can Māori protect their IP and guard against unintended consequences?
- **The status quo.** Māori organisations themselves are not necessarily actively integrating technology into their strategic planning, but rather, continue to rely on the same business activities that have generated revenue in the past.

5. Industry-led Workshop Discussions

The Industry-led workshop took place in Auckland over a full day on 28 March 2017. Around 30 participants from industry, academia and government all contributed to a series of questions posed by facilitator, Rod Oram, about New Zealand's potential for using technology to achieve great things economically, socially, culturally and environmentally.

NZ Inc. and Opportunities for Innovation

First, participants were invited to think reasonably broadly about NZ Inc. and the opportunities for this country to use technological innovation most effectively. Several themes came out, including: the importance of companies being involved in R&D; our responsibility to truly be kaitiaki (guardians of land, sea and air) as well as the difference between New Zealand's 'clean green' image and the reality; applying technology to farming; and niche manufacturing.

Participating in R&D is a highly important activity for companies to be involved in

The group discussed how important it is for businesses of all types and sizes to embrace R&D, rather than leaving it to government, academia and large corporates. Specific advantages of this across-the-board approach to innovation relate to moving New Zealand away from the current commodity (volume) approach to selling primary products. For example, technology could be utilised to shorten the supply chain, thereby supporting value-adding and niche products; businesses are arguably best placed to understand the practical nuances inherent in achieving such an operational improvement.

Outside of selling physical commodities, there is also a clear opportunity to market our food production expertise to the world. A key outcome of this may be supporting the growth of developing nations' own agricultural industries. With this in mind, R&D in the agricultural sector becomes an important area for focus

Despite the obvious benefits of all parts of the economy participating in innovation, Workshop attendees recognised that mid-size companies in particular are not as engaged in R&D as they could or should be. Further, it was suggested that high volume exporters

(of commodities) tend to have a low focus on R&D, while companies with more of a domestic focus tend to invest more heavily in R&D. While this view may or may not be true, it should be noted that this country has produced a number of high-tech, high-value exporters that invest heavily in research.

Primary Growth Partnerships[13] were offered as an effective example of government working with industry in a way that supports a wider innovation base. But more can be done. Ultimately, New Zealand has to be better at working together as a nation, breaking down silos and actively supporting innovation and collaboration. The government is seen as a key conduit for this, but also, there was acknowledgement of the important contribution start-ups can and already do make to move this country past being a commodity-based economy.

> *We need to take the growing entrepreneurship and innovation ecosystem that has built up around start-ups and help them to network at a wider scale.*

Kaitiakitanga: caring for and preserving the oceans and land is an important area for focus

Currently, the NZ Story of clean and green is considered 'more talk than fact', and this raises some important questions. Do we really understand the ROI of 'acting' green? How can we extract real value from being New Zealand?

In the first instance, attendees thought this opportunity was not as much about new scientific knowledge being generated as it is about connections and politics. For example, acknowledging what is really important to New Zealand's consumers (especially visitors), and then taking action to more closely align with this 'clean and green' vision. Technology could be developed to support and care for the environment that underpins the NZ Story, and to monitor the environment so the Story can be proven true.

Specific areas were identified where new technology can support kaitiakitanga. In New Zealand, biological systems are currently well measured, monitored and understood; however, there was acknowledgement within the group that the data being generated is not used in a co-ordinated or nationally advantageous way. To an extent this is not about creating new technology, but again, about connections and politics in the first instance. An interesting example was offered of large datasets being collected through a set of monitoring buoys managed by NIWA in the Southern Ocean. This is actually part of a global network of ocean observing floats called Argo[14]; all data collected is made freely available, and international collaboration is encouraged. Of course, this type of large scale data sharing has the potential to contribute to myriad aspects of New Zealand life.

'Intelligent Oceans' is a little used term that refers to utilising technology purposefully for monitoring and supporting the sustainability of the sea. Given the size of this country's Exclusive Economic Zone, New Zealand arguably has a responsibility to use technology to care for the ocean. Applying technology to managing the ocean's resources is discussed in greater detail in Section 6, particularly in relation to aquafarming.

Back on dry land, the question of how we might utilise New Zealand's indigenous plants was raised. There is currently strong consumer interest in natural bioactives (as opposed to synthetic extracts), particularly for health-related goods. There is also the opportunity, for example, to make a clearer link between Asian and Māori cultures in terms of traditional medicines.

Indigenous plants have not yet been fully explored at the compound level or as functional foods. There are many areas to explore, including: best methods for extracting high value compounds; identifying the potential to create new compounds through modifying plants; proving efficacy; and understanding the implications for Māori IP. It was agreed that there simply is not enough known currently about the New Zealand environment. For example, the high levels of UV light could result in higher levels of antioxidants in plants grown in this part of the world. When it comes to native plants, there are many more questions than solution ideas.

13 https://www.mpi.govt.nz/funding-and-programmes/primary-growth-partnership/

14 http://www.argo.ucsd.edu/

Start-ups garnered another mention with regard to protecting land and sea. The importance of supporting enviro-related startups was discussed. A good approach suggested was through PR and communications to tell their stories in order to increase public interest, and support investment-seeking.

Applying technology to agriculture

There was a great deal of discussion about the role of technology for improving farming practices in the areas of precision, automation and 'lights out', safety, and data.

One of the primary ideas centred on networking farms so that data can be easily captured and transmitted to the farmer to support decision-making around animal health and soil care, for example. There is already some work going on in this area - a cow-based Wi-Fi system that transmits bio-information from individual cows back to the farmer was mentioned by one participant.

Robots were also discussed in relation to primary production, chiefly in the areas of forestry (safety, planting, harvesting) and aquafarms (monitoring and harvesting). Robotics is discussed in greater detail below.

Niche manufacturing

Many attendees believed that technology was key to enabling New Zealand businesses to serve niche markets around the world. Small run manufacturing, and especially lowering the associated costs therein, was seen as a very worthwhile area for focus. Further, using digital technology to connect with consumers wanting our high value wares was seen as potentially very advantageous.

Focus on Technology

Next, participants were asked to focus on the key technology themes they thought would make the biggest different New Zealand. Four key themes emerged:

- Big data, sensing, smart materials, communications, and AI
- Virtual, augmented and mixed realities, virtual communities, and human connectedness
- Robots, drones, design, manufacturing, and operations
- Moonshots: e-farms, i-oceans, and consumer-focus

Big Data/sensing/communications/AI

Attendees identified a problem of disconnection between raw data and real world outcomes, while communications and AI were considered to play a crucial role bringing these together. In the first instance, participants thought that the solution did not necessarily lie in developing better algorithms, but rather, understanding applicability and embedding existing technology were both key.

Today, many businesses use data and analytics to a degree but too often there is no understanding of all that is possible, for example, in terms of understanding their customers. This is seen as an education problem, and the question was asked about whether students could help upskill business on how to use data for best advantage.

Another question the group raised was whether there was an opportunity for the SfTI Challenge to foster common or standard platforms and/or language to support more sophisticated use of analytics across the economy.

Ethics was also considered important: how do we ensure that data use is 'fair'?

These discussions, as well as those which took place pre-Workshop, made it clear there is currently a great deal of accidental discovery taking place around what's possible in terms of science and technology. Ideally a more purposeful knowledge base and information sharing system could be created so that individuals and businesses in New Zealand could easily discover what's technologically possible and where opportunities for collaboration are present.

Virtual Reality/augmented reality/virtual community/human connectedness

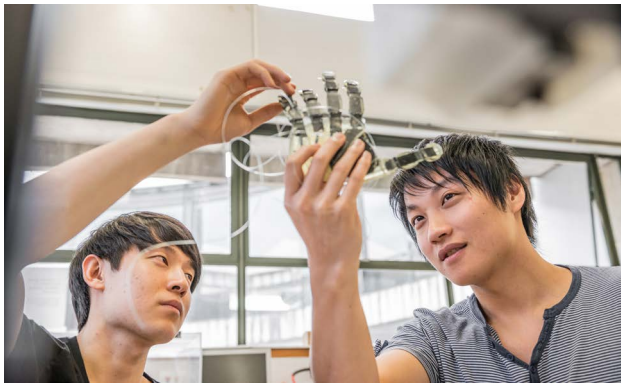
The family of artificial realities (virtual, augmented, and mixed) were seen as great tools for storytelling, enhancing connectedness, and for bringing far away people into the room. This technology has the power to help make New Zealand more cohesive, and help us understand ourselves and our history (including genetic history).

There was discussion around whether or not all of New Zealand might benefit from the kind of connectivity that virtual reality could provide:

- It could connect those in New Zealand's biggest cities to counter our smallness and isolation, and to virtually create meeting spaces and opportunities that support the quality of innovation that naturally takes place in densely populated geographies such as Silicon Valley
- It could connect people in smaller towns and communities to help reduce isolation
- A Māori lens/focus may well be important given this demography's growing economic impact and significant geographical spread across rural communities

Ultimately, however, the majority of participants agreed that in the first instance, Māori were the ones with much to gain through the broad concept of a Digital Marae/Whare.

Robots/drones/harsh environments/design-manufacture-operations



There were three main areas discussed where robots and drones could make a big difference for New Zealand in the future. First, the use of indoor drones was discussed. These can be particularly useful in factories when monitoring accuracy is required. Drones could also be used on farms for monitoring and integrating data.

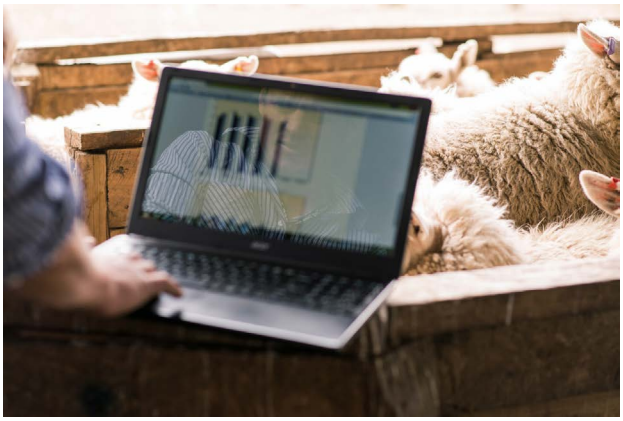
Second, flexible manufacturing robots that are cheaper and easier to reprogramme for a variety of tasks could contribute to servicing niche markets with smaller runs. Machine learning and AI may well have a role to play here.

Third, robots have a lot to offer in the types of harsh environments that are common in New Zealand. On land, forestry is an obvious example, particularly on steep hillsides and other high danger areas. Remote planting and harvesting were two specific applications discussed. Developing robots that can manoeuvre on rough outdoor terrain has proved difficult to date, however, if this could be achieved, there would be applicability across a wide range of sectors. A useful approach may be starting in learning environments where the ground itself is easily manageable but where safety is paramount, such as elder care facilities. This would enable functionalities such as vision and navigation to be perfected. In terms of marine scenarios, the idea of mussel ropes being automated, and supported by sensors, was mooted. The potential for remote underwater fishing robots was also mentioned.

Moonshots: consumers/e-farms/ i-oceans

A more general suggestion was made for New Zealand to focus on technology as a major export, while at the same time being self-sustainable in terms of food and other items typically imported.

> *We could position ourselves as the central creative tech hub for the Asia-Pacific*



However, there were three more specific Moonshots discussed.

First, focusing on digital consumers as individuals was seen as being key to achieving some of the ideas already raised. For example, being more creative in New Zealand's marketing by selling the Story of who we are would be greatly enhanced by better understanding what messaging resonates with people, and for targeting efforts to the most effective places. Further, this type of personalised approach would focus New Zealand on high value niches with smaller runs, quicker turn around, zero waste, and strong traceability. A key aim would be to help connect consumers with specific needs to New Zealand-based providers who can meet those needs.

On the other side of the coin, several participants wondered whether there was value in creating the 'virtual me' so consumers could avoid all the efforts of digital marketers by being incognito by default.

The other two Moonshots considered potentially worthwhile pursuing for researchers have already been discussed to a degree earlier in this report: e-farms and i-oceans.

Ideas for Spearhead Projects

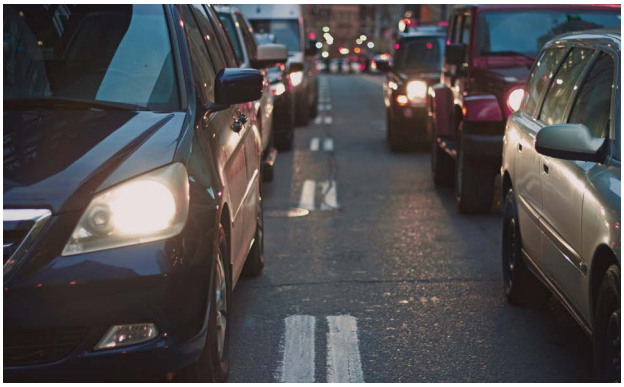
Ultimately, four potential Spearhead Project topics were chosen, and these will be discussed further in Section 6:

- The Digital Marae/Whare
- Intelligent Oceans
- Robotics for small scale production and harsh environments
- Personalised value chain

In addition, two other Spearhead ideas were discussed, however, it was decided these may best fall under other National Science Challenges and so the ideas will be passed on to other relevant research organisations.

Decongesting cities

The Productivity Commission estimates road congestion is costing Auckland as much as $1.25 billion a year. Several suggestions were made regarding how technology could contribute to decongesting cities.



Deploying intelligent transport systems, collecting detailed data, and using real-time analysis to support decision making, has the potential to optimise traffic management in new ways. Achieving this aim might involve bringing together myriad small New Zealand analytics companies, encouraging open innovation platforms, and creating technology in affective computing.

Other interests include: The New Zealand Transport Knowledge Hub, The Ministry of Transport, and ITS (intelligent transportation systems) New Zealand.

Improvements on the current Google maps dynamic route navigation and adaptation to traffic patterns recorded from GPS trackers in vehicles are sought. This would likely require more kinds of data being plugged into the system and smarter algorithms in order to optimise route recommendations for drivers, and support traffic authorities' decisions around dynamic traffic management.

Localised water sensing, monitoring and remediation

Water management is a key issue for New Zealand and of strong interest to Māori. There is a lot going on already in this area including in our seed projects. To take this project ahead we should look to see the new opportunities, such as new technology for monitoring water, and for remediation of water quality. There is also a strong link to the science challenge "Our Land and Water" (OLW). The original thinking was for SfTI to supply relevant technology for other challenges; this presents one opportunity, although from what we know of OLW content, there is no strong link for this. This project should not be in isolation from OLW and would need to involve (but not fund) one or more OLW researchers.

There is much work attached to this idea; it needs a clear analysis of what is happening and clarity of the opportunity for NZ. There is a strong focus on water quality and management, including Māori views regarding water.

Given how important water is across the globe, water management technology would have a large market.

6. Spearhead Project Directions

Bringing together all of the data and commentary to date has led to the development of four Spearhead Project directions:

- The Digital Marae/Whare
- Intelligent Oceans
- Robotics for small scale production and harsh environments
- Personalised value chain

Research will contribute to achieving these Spearhead visions through solving technical problems inherent within.

Connecting Fragmented Communities/The Digital Marae/Connected Whare

New Zealand Context

This direction is about connecting iwi and Māori with each other, both online and in digitally enhanced physical spaces. More specifically, this Spearhead direction is aimed at providing a place in which to store, and from which to disseminate, the history of New Zealand, transfer cultural knowledge and values, and create a space where cultural identity and tikanga can be strengthened and transferred intergenerationally.

Multiple technologies will need to be brought together to enable this goal. In particular, virtual, augmented and mixed realities, Smart Houses enhanced with sensors and the internet of things, and social media. Specific applications of the overall idea might include the collection, analysis and sharing of genealogy.

Social media is already being experimented with by some iwi to support connection, but what if we could think bigger, globally? Could this be a way to connect Māori living around the nation and the world? Could this be a way to pass on Mātauranga Māori between generations? And could a platform of this nature be exported to other indigenous cultures around the world?

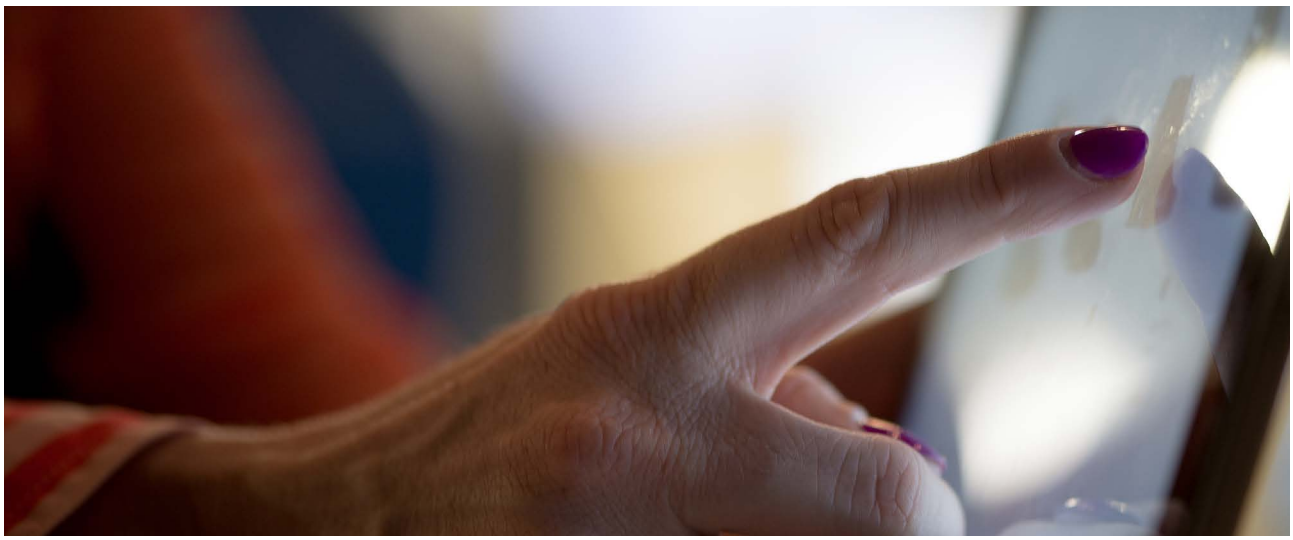
Why should we focus our attention here?

Cultural reasons

- The physical Marae is becoming less accessible and/or less relevant for some, especially young and urban Māori who may currently feel disconnected.
- Enhancing the connectedness between Marae and other Māori institutions is important, as is developing and supporting Mātauranga Māori.
- As a country, we have much more to learn about our own history and this could be one way of exploring, recording and sharing the past.

Economic reasons

- Māori are becoming increasingly influential in the agricultural, forestry and fishing sectors, so it's vital to support the voice of these communities.
- Connecting Māori landowners more closely with their whenua and land holdings will help in future decision-making through enabling greater participation.
- The importance of storying is becoming more relevant to the global consumer; Māori Stories are a key part of New Zealand's Story and can underpin efforts to market goods and services produced by the Māori economy.



Wider Context

This is a multi-pronged project area, and there is still work to be done in terms of determining scope, however, two specific technologies are likely to feature:

- Artificial realities (virtual, augmented and mixed)
- Sensors and IoT, particularly as they apply within Smart Homes

All the technological pieces of the whole are becoming more and more integrated: with each other and into all aspects of the real world. While sensors and IoT are already being used in Smart Homes to connect and manage devices and appliances, development of the type of experience aimed for in this Spearhead direction still remains closer to science fiction than reality. That being said, converging technologies make a more human/culture-centred offering more and more possible.

Outside of specifically science-related considerations, the issue of data sovereignty in an indigenous context will usefully be explored. Ethics and data sovereignty are issues that are continually in flux and yet are arguably not given the consideration they warrant. When it comes to using specifically Māori content, even less is collectively known in terms of processes and implications. An informative piece of thought leadership was recently published with a strong New Zealand focus: Indigenous Data Sovereignty; Towards an Agenda[15]. The document, while principally aimed at statistical data, provides useful learnings when it comes to the other types of knowledge that would likely come under the purview of this Spearhead direction.

Value proposition

There are multiple potential benefits for Māori:

- Perhaps the biggest value of artificial realities technology is in storytelling, particularly the history of Aotearoa. There is already some work going on in Gisborne looking at how artificial reality can tell these stories.
- It may be a good way of sharing and allowing interaction with a knowledge base. Whakapapa (genealogy) is an important body of knowledge that tribes put considerable effort into managing. How can we make it easier for all tribal members to plug information into the database, and, just as importantly, how can we make accessing this knowledge easy and enjoyable? Teaching and learning Te Reo Māori also fits under this banner.
- Technology could assist absent Māori landowners to actively participate in meetings and decision-making virtually ‘face to face’. Currently it can be difficult for landowners to be fully informed and involved in decisions around their land because they live out of area.
- Finally, outputs enabled by this Spearhead direction could be expected to support mana and identity through:
  - Re-imagining the marae as ‘the heart’ of Māori society
  - Longevity of kaumātua – they can continue to live on digitally
  - Reversing the loss of knowledge

15 https://press.anu.edu.au/publications/series/centre-aboriginal-economic-policy-research-caepr/indigenous-data-sovereignty

Vision and what success might look like

The Digital Marae is highly experiential as opposed to simply storing and disseminating information. However, the exact scope of this Spearhead direction is yet to be determined.

There is a vision of children growing up in a whare where every interaction is a learning opportunity, where questions are answered using the collective wisdom of the tribe, and where long dead kaumātua teach classes of rangatahi (young people) about tikanga Māori (correct ways of doing things) via hologram. Separate houses in a community are digitally linked with each other to better connect the people living inside them, and in turn, connections with institutions such as schools can be established.

Artificial realities can make a huge contribution to the success of this Spearhead direction, primarily through its ability to support education and storytelling:

- Augmented reality could be used for teaching te reo (and other languages) by immediately providing students with Māori/English translations, and descriptions for concepts and objects in the real world without having to go away and 'Google it'.
- Mixed reality could project historical events onto landscapes or show traditional activities in situ to allow students to see and experience things that have happened in days past, rather than simply reading the 'facts'.

Ultimately, success will only be achieved if the final products attract high levels of uptake by Māori of different ages and in different places. It will see Mātauranga Māori preserved, shared through the tools developed, and enacted in the 'real' world in myriad ways. Success requires that this direction is managed by Māori and for Māori.

Potential pre-technology project tasks

Given that this direction is about using technology to directly enhance human connectedness, there is some non-technology preparation work to be done. Specifically this is around the nature of disconnectedness, as well as data sovereignty and how knowledge is managed.

Preparation work that may contribute to a successful project:

1. Start with a gaps analysis
   a. the particular technology challenges (and this will also become more obvious as we head down that track)
   b. the nature of New Zealand's disconnectedness broadly, and more specifically, Māori disconnectedness
2. Purposefully explore ethics, protocol, and data sovereignty in this emerging area.

Science questions and stretch

Potential challenges include:

- IoT and sensor technology to make Smart Houses
- virtual, augmented and mixed reality technologies for creating visual presentations of cultural and historical knowledge and events
- interaction technology (such as facial and voice recognition) for people in Smart Houses
- new social networking technology to reflect indigenous knowledge and cultural protocols

Relevance to VM

While connecting people across time and geography could be usefully applied to multiple situations, for the purposes of SfTI's current programme of work, this is not about bringing all of New Zealand together, but rather, this is seen as a Vision Mātauranga project.

This would be a Māori led project with Māori governance. It has a strong potential to address all areas of the VM framework, including involving Māori ICT companies and other Māori organisations.

It is planned that a Wānanga process will guide development of this Spearhead Project to enable participants time for initial sharing and reflecting on what could be achieved and how it might roll out in practice. The SfTi Kāhui Māori, in partnership with FOMA, will initially lead the process until a more collectively chosen leadership emerges.

Key themes and portfolios involved

This is a complex research direction requiring multiple inputs in terms of technology. Further, the social and cultural elements are so integral to the overall aims, that social science and Mātauranga Māori must also be incorporated at the beginning and with ongoing work along the way.

SfTI themes:

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

SfTI portfolios

- Portfolio 1: Building NZ's innovation capacity
- Portfolio 4: Smart Services

Intelligent Oceans/smart sustainable farming in the ocean

New Zealand Context

Aquaculture is well-established in NZ, but has perhaps not yet begun to integrate new technologies into business-as-usual operations to the extent that land-based agriculture and horticulture industries have. There is little automation being applied, and a gap in sensing and monitoring capabilities. Those in the industry want to be constantly informed about what is happening inside their farms to guide what they do from the surface.

Aquaculture in New Zealand is built around three main species: Greenshell™ Mussels, Pacific Oysters and King Salmon. Just over $500m was generated by the sector in 2016, including $392m in export earnings[16]. Representative body Aquaculture NZ believes the industry can achieve $1b in total sales by 2025. At the same time, increasing inshore pressures, particularly environmental, have highlighted the need to look further out into our Exclusive Economic Zone (EEZ) for farming potential.

Why should we focus our attention here?

- New Zealand's EEZ is one of the biggest in the world and so we have a responsibility to understand how to manage this resource sustainably, especially within the current context of global warming, pollution and greater numbers of species under threat.
- Meeting the growing global demand for seafood will rely on increasing aquaculture production, and in order to capitalise on this, New Zealand must better utilise our EEZ. However, there are big technical challenges, particularly in off-shore farming, and these span all operational functions.
- Māori are heavily invested in fisheries, including aquaculture. The 2005 Māori Aquaculture Settlement assures iwi access rights to 20% of marine farming space, effectively strengthening ties to this sector of the economy.

There are potential links to the Sustainable Seas Science Challenge, not least because better aquafarming practices could reduce the take of wild ocean fish, as well as bycatch which puts some non-target species at risk.

16 https://www.mpi.govt.nz/news-and-resources/open-data-and-forecasting/situation-and-outlook-for-primary-industries-data/

Wider Context

According to a recent UN report[17], the annual wild fish catch has plateaued over the past 20 years at around 90 million tonnes. In contrast, Aquaculture production has seen steady growth; between 2009 and 2014 production increased from 56 to 74 million tonnes. Despite this, the UN Report notes that almost one third of global fisheries have been over-fished. Similarly, WWF's 2015 Living Blue Planet Report[18] states that marine populations have declined by almost half (49%) between 1970 and 2012. Clearly, a more sustainable approach to managing the oceans is required if we are to avoid further degradation.

Demand for aquaculture production is expected to rise sharply with a growing global population predicted to reach nine billion by 2050. Given the static nature of the wild fish catch, farmed fish will need to fill the demand-supply gap.

> ***Intelligent Mussel Beds are one example of where this Spearhead might bear fruit.*** *The big fishing opportunity is offshore, and mussels in particular grow better in the open ocean. However, beds are difficult to anchor (deep sea swells can be up to nine meters), it's difficult to monitor and treat disease and other health problems, and deciding when to harvest is an educated guess. Sometimes the farm is simply swept away and is lost.*

Value proposition

Applying new technologies to day-to-day aquaculture operations has the potential to reduce labour costs, enable better disease management, and maximise harvests. Further, automation supported by sensors and real time communications, as well as navigation/positioning, could unlock the huge deep sea potential for aquafarming, not only for shellfish, but also for fin fish.

Vision and what success might look like

Automation systems for aquaculture in the open ocean are developed that continuously monitor a range of metrics including location (GPS), temperature, health/pathogens, growth, size, and unexpected events. Crucially, this data would be transmitted back to farm management in real time to enable action to be taken. Underwater drones and sensors would be used to achieve this, while drones and other robotic tools may also undertake a variety of tasks underwater as needed.

Science questions and stretch

On warm, dry land, the technologies discussed under this Spearhead Project direction may not be overly complex. However, working up to 10 meters below the surface with lower visibility, currents, and increased pressure is an entirely different matter. Further, how can reliable communication between remote farms and home base be assured?

Relevance to VM

Given the significant investment by Māori in aquaculture and fisheries, technological advances in this area will reap benefits across iwi. This Spearhead also fits well with the concept of kaitiakitanga, and approaching sustainable ocean farming with this lens in mind will no doubt contribute to stronger outcomes.

Key themes and portfolios involved

This is a complex research direction requiring multiple inputs in terms of technology. The project area would benefit from consulting with experts outside of engineering, including marine biology and oceanography.

All the SfTI themes appear to be relevant to achieving the Intelligent Oceans Vision. In terms of SfTI portfolios:

- Portfolio 2: Agricultural and environmental technologies
- Portfolio 4: Smart Services
- Portfolio 5: Materials, manufacturing processes and applications

17 http://www.fao.org/3/a-i5555e.pdf
18 http://assets.wwf.org.uk/custom/stories/living_blue_planet/

Small scale production, learning robots and robots in harsh environments

New Zealand Context

This Spearhead /direction has two separate but related streams:

1. Semi-autonomous, easily reprogrammable manufacturing robots

For manufacturing, robots that can be easily and cheaply reconfigured will be highly useful for small production runs servicing niche or totally individualised markets. They will enable small scale and short term production. Work in this area could support new business models focused on individualised manufacturing.

2. Robots for harsh environments

When it comes to primary industries, New Zealand has a great deal of unstructured physical terrain; it is harsh, hard to control, difficult to navigate, and dangerous for human workers. Using robots in place of humans could unlock previously unusable land resources, save lives and reduce costs.

In terms of the foundational science and technology, there are similarities across both streams. Artificial intelligence (including machine learning), vision, IoT and sensor technology all need to be developed for these specific contexts.

Why should we focus our attention here?

- In terms of niche manufacturing, there is arguably a growing movement in New Zealand pushing for a move away from commodity economics, towards higher value exports. Developing cheaper, more efficient small scale manufacturing tools would support such a shift.
- Technological developments in niche manufacturing can be applied across sectors.
- With regard to harsh environment robots, New Zealand has a lot of rough countryside on which farming of one kind or another is carried out – it is dangerous work, and some land remains economically unviable due to accessibility costs.
- Māori are highly invested in forestry, and unlocking land previously considered too expensive or difficult to farm would pay great economic dividends.
- Technology developed in both areas would prove highly exportable.

Interestingly, copious amounts of big data from biological systems is being collected and stored in this country, but it is messy and unstructured, which makes it difficult to clean and analyse, let alone apply. However, greater expertise in managing unstructured data will be of great benefit in this area, particularly in terms of machine learning. Of course, learnings from unstructured environments can also be useful for more standard environments.

Wider context and value proposition

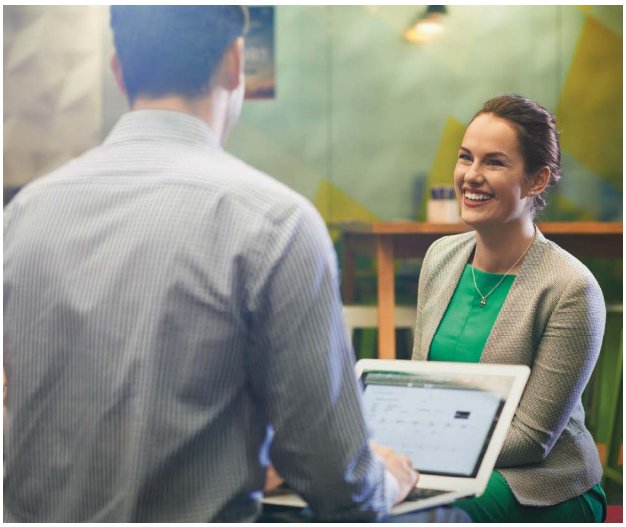
Recent decades have seen a significant trend of large scale manufacturing plants being off-shored from the West to countries with lower labour costs such as China and India. However, more specialised, high value manufacturing has been less susceptible to this disruption due to the high levels of expertise and technology required. Additive manufacturing is now making great strides and looks to be one factor dampening the popularity of off-shored mass production as a standard practice even in less specialised areas.

Further, the use of robots is increasing exponentially in factories around the world, and this serves to render the cost of labour less relevant to choosing manufacturing sites. Demand for semi-autonomous, short-run robots should also increase, especially as businesses begin to use data to move away from serving market segments towards meeting individual customer needs.

In terms of robots for harsh environments, the applications really are endless. Forestry is one industry that could benefit tremendously from greater use of robotics. Between 2009 and 2013, there were 28 fatalities reported, making forestry the most dangerous industry in New Zealand over that period. Since then, however, there has been a sharp drop in the number of deaths and serious injuries, and this is a result of investment in steep slope harvesters and associated safety equipment. For example, the ClimbMAX (Kelly Logging) is essentially a 42 tonne repurposed excavator, which has all but eliminated worker-risk while reportedly increasing production by 20% or more. The ClimbMAX is now being exported, albeit in low numbers. Another piece of harvesting equipment still in early stages of development is the remote controlled tree-to-tree harvester developed in collaboration with SCION. This equipment moves between trees without touching the ground, and also presumably has export potential.

Vision and what success might look like

This Spearhead direction would see greater reliance on smart robotics to unleash economic potential and (in harsh environments) reduce risks to people.



In manufacturing settings, producers would be able to confidently and profitably exploit global consumers' growing expectation of individualised service and quick delivery. Underpinned by strong digital marketing and ecommerce tools, New Zealand-based producers could capitalise off direct relationships with their customers by responding quickly to changing needs.

In harsh environments, the forestry industry in particular will continue to see death and serious accident rates decrease, and productivity increase as robotic equipment moves from being remote controlled to semi-autonomous. The resulting technology is able to be applied to other sectors, and to exportable products.

Science questions and stretch

Robotic equipment in both streams currently requires a great deal of human input to operate; the extent to which robots can learn and be semi-autonomous is perhaps the greatest challenge here.

Machine learning will be key, and for the harsh environment scenario at least, utilising the vast amounts of unstructured biological systems data generated within New Zealand will be advantageous. Biological irregularities should be at the heart of anything to be used in the environment.

Relevance to VM

Māori are already highly invested in forestry and so any economic and safety gains made possible will positively impact the Māori economy. Further, when it comes to niche manufacturing, advancements in small runs will better enable Māori operating in the primary industries to add value to produce, and directly market to more discerning global consumers.

Key themes and portfolios involved

Both manufacturing and harsh environment scenarios are very focused on engineering science and technology.

SfTI themes:

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

SfTI portfolios:

- Portfolio 2: Agricultural and environmental technologies
- Portfolio 4: Smart Services
- Portfolio 5: Materials, manufacturing processes and applications

Personalised value chain / the individual as a customer

New Zealand Context

New Zealand exporters operate primarily in the business-business (B2B) space by selling either low value commodities to companies who subsequently add value, or we use intermediaries to sell products to consumers, reducing our profit margins. Further, successful New Zealand entrepreneurs tend to spend a large percentage of their time travelling to foreign markets, or they relocate completely. Overall, we are not achieving the best outcomes.

What if there was a way that New Zealand-based businesses could gather very detailed and correct intelligence about overseas markets (including more individualised consumer needs and behaviour, and competitor activity) so that we operated in a more business-consumer (B2C) way? People and profits could both stay onshore.

This, of course, moves us away from focusing R&D dollars primarily on product development, towards thinking in terms of business model-development and marketing-development. How do we use technology such as AI and automation to supercharge how we market and sell ourselves to the world? How can we harness digital connectivity to enter into relationships with individual consumers, especially when they haven't even found us yet?

It is assumed this would be a digital solution that makes use of the massive amount of data generated online, not only to gather knowledge about markets, but also to communicate back using clever, individualised marketing strategies. New Zealand has a great story to tell, and economic success will be greatly enhanced through targeted messaging and enabling better customer experience (including online).

Why should we focus our attention here?

- As a small export nation, New Zealand would benefit from better connecting with individual consumers. How do we let them find us easily so they can let us solve their problem? How do we reduce the physical miles between us and our markets using online?
- At a time when new technology is enabling new business models, New Zealand should be proactively creating new ways of selling to the world. How might we help network consumers so they can be more proactive in the choices they make?
- In order for New Zealand to move from a commodity economy, the value/supply chain needs to be optimised for small runs of products as consumers seek a more personalised experience. How could we better utilise online-generated data to support the development of marketing AI?
- We don't yet know what the possibilities are. For example, given that we are a food-producing nation, could we be a leader at matching offerings with consumers' nutrition needs? How could we apply technology such as blockchain differently to achieve new aims?

Wider context and value proposition

Technology is moving at pace in the area of sales and marketing in the digital ecosystem. Customers are routinely being tracked online so that marketers can tailor communications and present online experiences that encourage buying behaviour.

> *This Spearhead aims to go several steps further towards gathering intelligence about pre-customers, as well as competitor behaviour and other relevant factors in overseas markets.*

Being able to connect directly with global consumers would be invaluable for a small exporting nation such as New Zealand. From a practical point of view, it would mean we could move away from selling low cost commodities to markets, and sell high value good and services to people who want them; simply put, it would be the difference between being price takers and price makers.

Vision and what success might look like

Work in this area could enable new business models. For example, the 2016 winner of the UK Online Butcher of the Year award focuses on providing heritage meats; what would be a tiny niche market at a local level is transformed into a sizeable business opportunity by using an ecommerce platform with national reach. Technology has made this possible.

Leaders of export businesses would have online access to all kinds of information they usually have to travel to a market to discover, including wider consumer trends and competitor activity. They could also access current unknowns such as non-customer behaviours and needs.

Using another example, as the emphasis on clean safe food origins and environmental performance increases, a food producing nation such as New Zealand would do well to become experts and leaders in supply chain management. Blockchain is suggested as a valuable technology in the field. But this is not simply about safety and logistics, it is also about telling the New Zealand Story and/or the Māori Story and proving our stories to be true.

Science questions and stretch

This direction centres first and foremost on tracking people's online behaviour; this has become infinitely more easy to do for existing customers, but for those a business does not already have a relationship with, it can be very difficult. How might blockchain be used in personalise the supply chain, and can it be reverse engineered to provide customer-centric data?

Many more questions remain. Are big multinationals already solving the relevant technical problems? Are there technical considerations specific to New Zealand? What are the opportunities for New Zealand researchers and industry to partner with multinationals to create solutions? How could such technology support the New Zealand Story?

Relevance to VM

When it comes to niche manufacturing, direct relationships with consumers will better enable Māori operating in the primary industries to add value to their produce, and directly market to more discerning global consumers. Further, sharing stories and other IP can be done in a more controlled way, as opposed to mass dissemination where cultural taonga can then be misappropriated.

Key themes and portfolios involved

This Spearhead direction has a strong IT focus.

SfTI themes:

- IT, Data Analytics and Modelling
- Vision Mātauranga

SfTI portfolios:

- Portfolio 4: Smart Services

Information Sources

Primary

- Steve Wilson, Talbot Technologies
- Kerry Topp, Datacom
- Graeme Muller, NZTech
- Traci Houpapa, FOMA
- Brett Hewlett
- Lewis Gradon, F&P Healthcare
- Andy Hamilton, The Icehouse
- Rob Fyfe, Icebreaker
- Dr Sean Simpson, Lanzatech

- Katharina Ruckstahl, Kahui Māori
- Margaret Hyland, Chief Scientist
- Reece Moors, Callaghan

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- Singularity University
- Gartner

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