SCIENCE FOR TECHNOLOGICAL INNOVATION

Kia kotahi mai –
Te Ao Pūtaiao me
Te Ao Hangarau

National SCIENCE Challenges

SCIENCE FOR TECHNOLOGICAL INNOVATION

# Legacy Report

AUGUST 2024

“There is a lot of risk. There is a lot of risk in investing in a project, and they [SfTI] invested in high-risk projects. Amazing ideas, cool ideas that might not work. They invest in the people, and they invest in the project. First, the people, then the project. And that's what SfTI did with the hope that these people are going to create that network that will nurture the next generation. Those investments are bringing more capability to all these institutions, and that comes back to the New Zealand people.”

BALAM JIMINEZ, SFTI RESEARCH LEADER AND FOUNDER OF TONALLI MOANA

# Contents




## Acknowledgements

Thank you to those from across the SfTI community who made themselves available to be interviewed for this legacy piece. Thank you also to those who have read drafts and given feedback along the way, especially Sally Davenport, the Challenge Director. In addition to drawing heavily on interview content and past reports, the articles written by SfTI's Senior Adviser Insights, Communications and Influence, Georgina Wiles, have been used throughout this document.

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# Foreword

## He hiringa hangarau, he oranga tangata; Innovation in technology for the benefit of people

**Technology is only useful if it benefits our world, including humanity, in a positive way. And it is people that create technology. That is why SfTI's whakatauākī has been pivotal to how we have approached our mission, to 'enhance the capacity of Aotearoa New Zealand to use physical sciences and engineering for economic growth' and we would add 'and prosperity'.**

There was a two-fold purpose in putting this legacy document together. Of course, first we wanted to capture all the processes and programmes that SfTI put in place. Almost nine years ago SfTI was launched with a clear mission plus a $106 million investment, but a blank canvas in terms of how we would achieve this mission. We end with an economic analysis that says our efforts should return that investment by at least 300% per year, if not more, in coming years.

We also wanted to convey the sense of excitement and energy we all felt along the way. We were operating at arm's length from government (with appropriate controls in place) and could take risks and experiment, be flexible and open to change, in ways that none of us had ever experienced before in our own research careers. Yes, we were working in a totally ambiguous state, but that meant it was also permissive and tolerant of mistakes. We did make some, we are the first to admit (and they are documented in this report), but we flexed and learnt and moved on in ways that only meant we did a better job in future. It reminded me very much of the Einstein phrase my master's students once had printed on a class T-shirt (and I still have mine): "if we knew what we were doing, it wouldn't be called research".

I come back to the people though, it has always been about the people and relationships and connections as is so beautifully captured in our concluding short documentary, 'Connected for Innovation'. We very much cared about the technical achievements, but that is only one aspect of the research journey. We were tasked with enhancing capacity, and it is our researchers' capacity that we worked to enhance. As one of our researchers so eloquently and succinctly put it, "first the people, then the projects".

Hopefully this report will convey the way the SfTI team put the researchers as people front and centre with our Capacity Development Programme, our one-on-one mentoring of less experienced project leaders, our openness to pivot (well before the word became a meme during Covid) if projects needed to, and extra support for the underrepresented in the funding demographics of physical sciences and engineering (women, Māori and Pacific Islanders, and early career researchers).

So, did we achieve our mission? We would whole-heartedly say yes (exceeded our impact KPIs), and we hope that the behavioural change we have engendered in our community, including the skills and connections that underpin innovation, 'stick' for the long term.

It has been an exhilarating journey and I want to acknowledge those that came before me and those that lasted the marathon. Essentially, we created a community with shared values and vision, which will endure after we are gone within those who connected with us. I'm well known (possibly with a cringe-factor) for saying that 'you can check out of SfTI, but you can never leave'. So SfTI has checked out, but we trust that the community of those who engaged in multiple ways - as researchers, students, research and technology transfer office managers, our project research partners, industry advisory groups and impact advisers, our fourteen partner organisations, including our host Callaghan Innovation, our Kāhui Māori, our Board members, advisers and observers (past and present), our Leadership Team and Programme Office members – will always remember with satisfaction their involvement with SfTI and, while all have 'checked out', will never l ose that sense of ambition and purpose of 'technology for people'.

**We end with an economic analysis that says our efforts should return that investment by at least 300% if not more in coming years.**

# Executive Summary

As the National Science Challenges come to a close, it is useful to look back on SfTI's contributions over the past decade. This current document revisits some of the NSC establishment history for interest, and then delves into the more detailed aspects of SfTI's Mission and the innovation needed to achieve it.

First and foremost, SfTI took the **Mission-led** approach seriously, learning from international examples of best practice, such as the work of Mariana Mazzucato, and hosting Mission Labs in Tranche One to ensure its research was informed by industry and Māori. A focused Spearhead development process was also created, which brought together best teams rather than competitive individuals via Researcher Workshops. It was recognised that the only way to meet complex problems and opportunities was to bring in multiple knowledge domains, perspectives and skills, and this would require **collaboration**.

A crucial element of genuine partnership in Aotearoa New Zealand is ensuring Māori knowledge, people and resources, are fully involved in the research process, and so the **Vision Mātauranga** policy was foundational. The Kāhui Māori were particularly influential in this area, with the rōpū involved in a range of activities such as creating practical assessment tools (*Te Tihi o te Maunga* and *Te Aromatawai*) and advocating for higher funding levels for VM-relevant research. Further, it was clear that **capacity development** needed to be a focus, and this has resulted in researchers being just as important as the research itself.

It is fair to say that SfTI has been very **innovative in how projects were developed and managed**, with some very interesting practices being refined. These include managing the small high-risk Seed projects, simplifying research administration practices, pivoting and discontinuing projects, and experimenting with the Concept-Knowledge (C-K) Method to form teams.

The **Building New Zealand's Innovation Capacity (BNZIC) Spearhead** allowed a purposeful examination of the innovation process, particularly at the interface between researchers and industry/Māori. The team has identified a number of factors that support more impactful research, and have communicated these findings across numerous platforms.

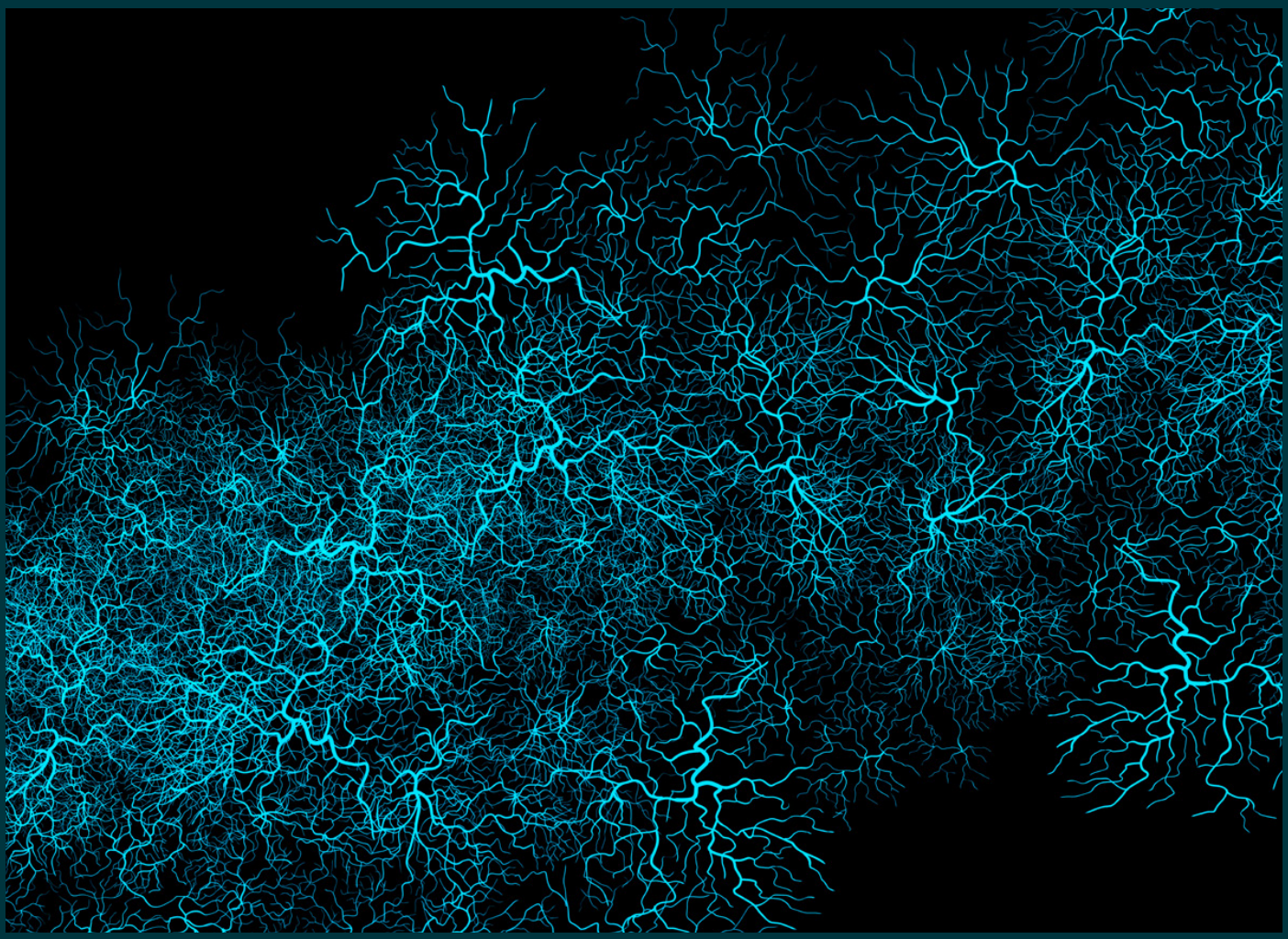
**Science excellence** has not been forgotten. Challenge leadership included Science Advisors who worked with the Board to inform decision-making, and two separate Science Reviews were carried out, one by an international panel of experts.

In terms of **managing the Challenge**, the Board, Kāhui Māori, Leadership Team and Programme Office have all been guided by SfTI's Whakatauākī: *He hiringa hangarau, he oranga tangata; Innovation in technology for the benefit of people*. Made up of very skilled and committed individuals, these teams coalesced around the Mission, and were able to capitalise on the generative opportunities presented by the NSC structure, as well as solve problems creatively when they arose. Their approach to Intellectual Property management, for example, saw them co-create novel contract clauses that protect mātauranga Māori and taonga species within the research process and beyond.

It will be difficult to identify the full **impact** of the SfTI Challenge given the wide scope, long timeframes involved, and multiple influences working concurrently. However, using Additionality as a reference point helps tease out some signs. In terms of *Input Additionality*, SfTI has supported research that has gone on to be co-funded by other organisations, and has established relationship with others, such as the Federation of Māori Authorities (FOMA), that have benefitted both parties. *Output Additionality* can also be seen through the various start-up companies that have emerged from the SfTI community. The NZIER found that significant economic benefit is likely to be realised into the future as a direct result of research funded by the Challenge.

But it is perhaps *Behavioural Additionality* where SfTI has made the most significant contribution, and this can be seen in the learning experienced by individuals and organisations connected with SfTI. The Capacity Development (CD) Programme has improved the relational and human capacities of researchers and leaders alike, particularly in the areas of Vision Mātauranga, leadership, and commercialisation skills. Additionally, new best practice processes and artefacts have filtered across RSI institutions through contracting practices (e.g. Intellectual Property) and the supportive push for commercialisation, among other things.

We know that SfTI's contributions in these areas are impactful because of BNZIC's work, and the current document finishes by presenting some of their observations. There are clear signals that investment in the SfTI NSC has resulted in benefits additional to those that may have been achieved had the funding been awarded to traditional research institutions, but only time will reveal the extent of these benefits.



# 1. Introduction to the National Science Challenges

The National Science Challenges (NSCs) were an initiative aimed at supercharging the application of science for meeting some of Aotearoa New Zealand's greatest challenges and opportunities. Challenge development was overseen by a National Science Challenge Panel chaired by Sir Peter Gluckman, who was at that time the Prime Minister's Chief Science Advisor. It was informed by public submissions as well as consultation with researchers and research providers.

**Five key principles guided these new organisations:**

1

### Mission-led

Each Challenge is mission led and focuses research on achieving the Challenge objective and outcomes. Each research plan provides a credible impact pathway of research and related activities to achieve the outcome of the Challenge.

2

### Science Quality

Each Challenge is dynamic and includes mechanisms to bring in new ideas, researchers, and research providers to refresh the Challenge. Each research plan involves identifying and selecting the best science to address the Challenge. Critical research capabilities including Mātauranga knowledge need to remain dynamic and must continue to be built and evolve to maximise outcomes for New Zealand.

3

### Best research team collaboration

Each Challenge involves purposeful collaboration between researchers, across a number of research providers. Each Challenge is clearly linked with international research activity that supports the achievement of the Challenge.

4

### Stakeholder engagement & public participation

Each Challenge involves public outreach and exhibits strong engagement between researchers and intended end users of the research activity, including, in some cases, obtaining investment from end users in the Challenge's research.

5

### Māori involvement and mātauranga

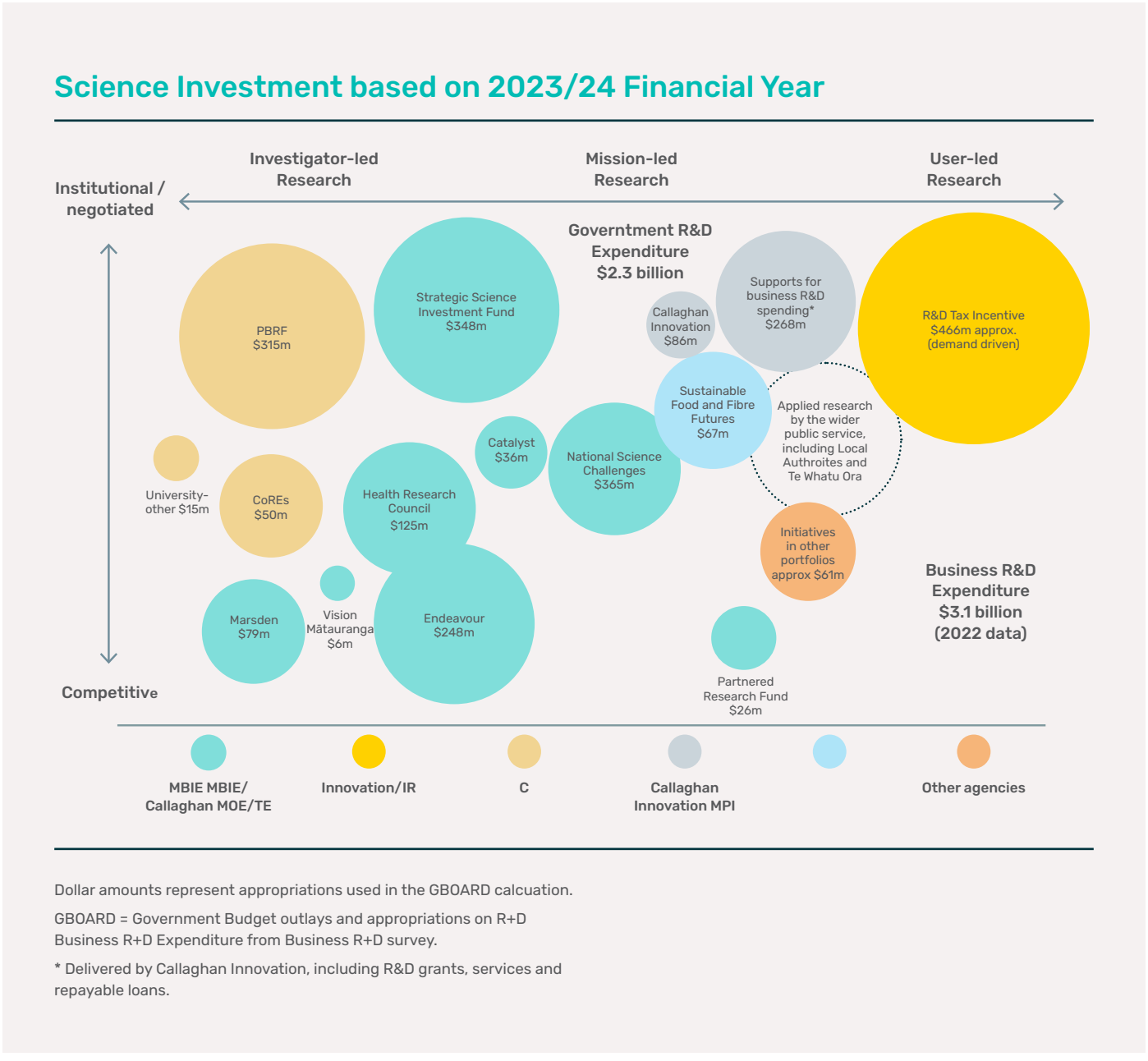
All Challenge research gives effect to the Vision Mātauranga policy.

Ultimately, 11 Challenge areas were approved, each with a unique Mission, and the Panel called for a single fulsome proposal for each. This in itself was a sign of things to come because it required researchers to come together and collaborate rather than compete against each other in creating the detail for each Mission area.

## WHERE DID THE NATIONAL SCIENCE CHALLENGES FIT WITHIN THE WIDER RSI SYSTEM?

The Challenges were positioned at the centre of the ecosystem - they were Mission-led (as opposed to being primarily investigator-led or user-led), and they applied a mix of negotiated and competitive funding mechanisms. The sum invested was modest when compared against some of the other larger funds.

### Government Expenditure in the RSI System[1]




Dollar amounts represent appropriations used in the GBOARD calcuation.

GBOARD = Government Budget outlays and appropriations on R+D Business R+D Expenditure from Business R+D survey.

* Delivered by Callaghan Innovation, including R&D grants, services and repayable loans.

1. Source: Ministry of Business, Innovation and Employment. (2023). *Briefing to the incoming Minister of Science, Innovation and Technology, November 2023.* (p23)

# 2. Establishing Science for Technological Innovation (SfTI)

"Ultimately, SfTI has always been so much more than simply a funder of scientific research. It brought together diverse groups of people and organisations from the outset, with often previously unconnected areas of specialty, and it had real world aspirations for science and research activities."

## WHO WAS INVOLVED AT THE BEGINNING?

Early contributors to SfTI's direction included Shaun Hendy, Richard Blaikie, Margaret Hyland, David Williams, Richard Templar and Kathryn Beare. Others, who have continued in the Challenge through to its conclusion, include Sally Davenport, Bruce MacDonald, Te Taka Keegan, Don Cleland, Katharina Ruckstuhl, Geoff Chase, Elspeth MacRae and Ian Woodhead. The establishment group was made up of experts from a range of disciplines who held different ideas about what was important, so negotiation became essential.

## WHY DID PEOPLE PUT THEIR HANDS UP TO DEVELOP THE SFTI CHALLENGE?

Initially, it was about ensuring their research and/or research organisation would have access to this new funding source. As one of the original architects remembers, they became involved without really knowing what they were signing up for:

*"It wasn't clear where it was heading and what it might look like. It was obviously a different funding mechanism, but it wasn't clear how that would work in practice."*

Others were invited into the process because of their skills and experience. For example, Sally Davenport was recruited by Shaun Hendy and Richard Blaikie because of her work with the MacDiarmid Institute, Katharina Ruckstuhl was invited to bring Māori representation and her social science expertise, while Urs Dallenbach was brought in to work on the strategy and innovation study of the Challenge as an entity.

## HOW DID THE PROCESS WORK?

The government set general terms, and then the task of determining how to apply those guidelines within set parameters began. As some remember, it was a loose process involving many viewpoints and considerations, but eventually a direction emerged:

*"We sort of sat in a room with 30 people and effectively tried to map out who would be the team to get this going in a more practical sense. And it was a bit bizarre because it was a combination of trying to not have it all in one institution, getting geographic representation, getting different points of view, and yet ultimately it probably did set up people that were at least open to doing things a bit differently."*

*"Everyone had quite different ideas about what was important - there was no absolute consensus on exactly what should be in and what should be out, what should be the focus and what shouldn't be. And so there was an element of trying to do a little bit of everything to keep everyone happy."*

To help focus the myriad ideas, leadership expert Lawrence Green was asked to facilitate 'sandpits', from which the first Spearheads emerged. One aspect of the Challenge's focus area - the combination of capacity development and physical sciences and engineering - was that it was not attached to a stable of legacy projects that needed to be accommodated (as there was for some other NSCs such as those in the health domain), so in a sense, it was a fresh start.

Forming the Challenge Themes involved a lot of discussion, and the eventual groupings could have been made along a number of different lines, but, as one participant said, that level of detail was not vitally important: "*The Themes are a way of describing ourselves, but there could have been other different ways that would've been as accurate and probably done the job equally well, because at the end of the day, the projects we did and the processes we used were driven through other things.*"

## WHAT DID THEY END UP WITH?

The original SfTI proposal was rejected by MBIE because it had focused too much on technical projects at the expense of 'enhancing capacity'.

The second (successful) version of the proposal amped up capacity development with the assistance of the social scientists who had joined the establishment group. The writing team allocated dedicated budget to capacity development, something that has proved very effective in removing barriers to participation:

*"There was the emphasis on collaborations, a specific emphasis on building capacity and the different sorts of capacity - it wasn't just about technical projects."*

The final proposal was submitted in May 2015, and after a positive response from MBIE, the Challenge was launched a few months later in September with an event attended by 200 guests.

## HOW WAS THE HOST CHOSEN?

Members of the establishment group advocated strongly for the Challenge to sit within Callaghan Innovation's purview. This pairing offered the potential to form a mutually beneficial partnership, although this never eventuated to the extent it might have due to Callaghan's change of direction and frequent change of personnel:

*"The whole idea of SfTI being strategically placed into Callaghan as the host was that SfTI was the pipeline of innovative ideas and Callaghan would essentially pick the eyes out of it and say, 'Oh yeah, we are working with company X.' SfTI was researcher-facing, but industry-relevant, and Callaghan was industry-facing, but researcher-relevant."*

Nevertheless, there were still benefits to being hosted by this type of organisation because while the Challenge was at arm's length from the government, there was also a sense of discipline inherent in being attached to a Crown Research Institute.

Ultimately, this course of action proved to be a good one. Callaghan Innovation allowed SfTI a high degree of autonomy, which had not been guaranteed by the establishment guidelines. At the same time, SfTI made an early decision that while Callaghan's researchers could participate in the large Spearhead projects, it should not seek funding from the Challenge for its research.

*"One of the things I've admired about Callaghan is that they have allowed SfTI to determine its own destiny. They could have stepped in at any time and pulled the plug and said, 'No, we want a bit more control of this'. That 'freedom to operate' as an autonomous business unit within Callaghan has been an important part of SfTI's journey."*

## SFTI BEGINS

SfTI's Mission was *to enhance the capacity of Aotearoa-New Zealand to use physical sciences and engineering for economic growth and prosperity*. While 'economic growth' was the original official purpose from MBIE, this morphed slightly over time, in part due to the influence of the Kāhui Māori who promoted a wider interpretation of benefit.

# Science for Technological Innovation National Science Challenge Mission

SfTI's aim was to contribute to a future Aotearoa New Zealand with a vibrant, prosperous, technology-driven economy in which researchers could fully integrate with, and contribute to, government policies and industry strategy, and where business could deliver novel high-value products and services to meet market demand.

| | |
|---|---|
| **To enhance** | Increase, intensify, improve, accelerate |
| **the capacity** | knowledge, ability, skill, talent, capability, power |
| **of Aotearoa New Zealand** | researchers, scientists, Māori, businesses, communities and government |
| **to use** | harness, design, develop, progress, implement, produce |
| **the physical sciences and engineering** | physics, chemistry, mathematics, materials, manufacturing, data, analytics, robotics, sensing, technology, Mātauranga Māori |
| **for economic growth** | for prosperity, wellness, wealth, oranga tangata |

# 3. Achieving SfTI's Mission

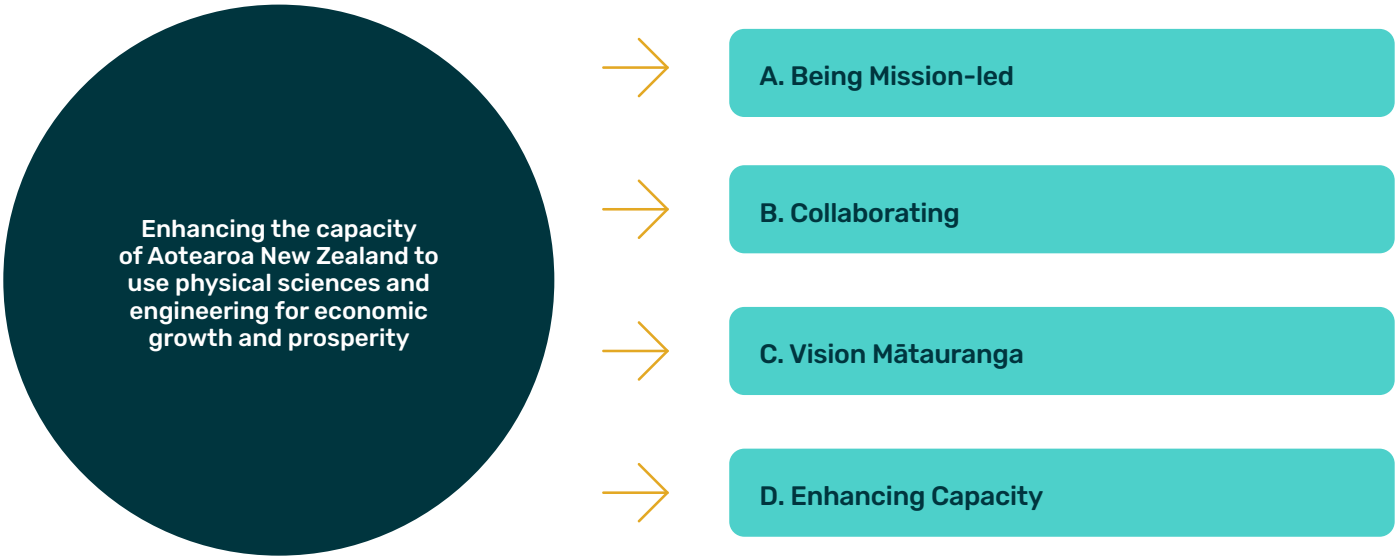
In total, SfTI funded 11 large *Spearhead* research projects, 86 smaller *Seed* Projects, ten *Ending with Impact Projects (EWIPSs)*, and five *Early Career Researcher Bolt-on Projects (ECRBOPs)*. Just over 740 researchers have made up the SfTI community, including 95 Māori, 219 Women, 307 emerging career researchers (post-doc/PhD/masters), and 281 rangatahi (18-35 years of age) researchers. They have come from across 58 different organisations.

But the unique aspect of SfTI was that in addition to delivering research outputs, its remit was to raise the capacity of Aotearoa New Zealand to utilise science; it was in changing the behaviour of researchers, businesses and Māori communities, that the greatest improvements in innovation could be made:

*"SfTI's twenty-year view is that it is the processes we have instigated around Mission Labs and forming co-innovation teams 'mid-stream' with Māori and industry in the room for the entire journey, that lays the fundamental platform for this long-term. Moving to a far more collaborative, 'NZ Inc.' approach for a technology driven economy must provide benefits for all society."*[2]

Growing an organisation that could actually perform such a task required thinking outside the square, and SfTI's early leadership rose to the challenge. In the first instance, it was fully committed to being **Mission-led** and as such drew on wisdom from outside of the research community to help determine its research directions. It also recognised that the only way to meet complex problems and opportunities was to bring in multiple knowledge domains, perspectives and skills, and this would require **collaboration**. A crucial element of genuine partnership in Aotearoa New Zealand is ensuring Māori knowledge, people and resources, are fully involved in the research, and so the **Vision Mātauranga** policy was particularly important. Further, it was clear that **capacity development**, while a general aim of the Challenge, needed to be a focus for the researchers themselves. These four elements have stood SfTI in good stead for achieving its aims.

## Enabling SfTI to Achieve its Mission




2. Science for Technological Innovation; Second Tranche Forward Strategy (2019-2024). (p6)

## A. BEING MISSION-LED

**"We focused on impact as the goal and then we helped people to coalesce around that. Does everyone want clean water? Sure. Is biosecurity important to the future of Aotearoa New Zealand? Of course. That's where the Mission narrative worked for us, it helped us to get researchers to think beyond their specific projects and partners (industry, Māori, community), and to think beyond their specific KPIs."**

In a sense, SfTI did not develop a cast iron strategy at first, rather, the team experimented with ideas that might advance the central Mission, and in this way was able to achieve its dual aims of both enhancing capacity to use physical sciences and engineering **and** producing innovative technology:

*"The Mission is what drives us and should be really important and always top of mind because ultimately that's what we're here for. But the fluidity allowed it to develop really well, so the process sort of came along with it as opposed to starting with a very set defined process."*

### Mariana Mazzucato

SfTI Leadership became interested in Mariana Mazzucato's work early in the first tranche. Given the lack of local examples of Mission-led science, the international rhetoric around 'Mission-led' provided the language needed to communicate this novel approach to others, particularly researchers. Concepts such as *'Working with the Willing,'* and applying top-down management together with bottom-up processes across a portfolio, both come from Mazzucato:

*"It did give us some legitimacy in what we were trying to do. We could say, 'Well look, some of these things are happening overseas, so get with the mandate'."*

*"It gave us a mechanism to talk to people about what Mission-led research meant because researchers understand 'investigator-led', they understand 'user-led', but not all of them even understood what a Mission was or how then you would construct a research program under that sort of approach. So 'Mission-led' transcends a single use, it transcends a single researcher's interest; it's collective."*

Further, Mazzucato provided a framework through which research projects and investments could not only be selected, but then also easily justified and communicated to ordinary people not working within the RSI system. As one member of the Leadership Team described it, simplicity was one sign that a focus area could be truly Mission-led: "*A Mission should be something that most people would say, 'That's worth investing in.*"

*"The most important thing is that those who are outside academic spheres or CRIs or other research institutes actually understand that there's value in the science, in the technology, and that it can lead to gains for your business or your community, whether that's environmental or health or commercial. And so, one of the things I think that SfTI's been really good at is saying, 'This is about using what we do, not just thinking of more great ideas,' because we've got huge numbers of ideas, fantastic ideas, but how do you make those ideas work in a space where people want to actually use it or take advantage of it."*

Of course, as another member of the Leadership Team noted, despite the huge communications efforts made across all the Challenges, most ordinary people know nothing about this approach or what has been achieved over the past decade. This is perhaps a lost opportunity because as Mariana Mazzucato has said, Missions are most successful when they are part of a wider context of geopolitics, national government policies and large scale linkages with the private sector, and when their aims are baked into a wider national discourse. Aotearoa New Zealand's NSCs did not achieve this level of interconnectivity more generally.

### The Mission Labs

SfTI's two Mission Labs were significant events in triggering the Mission-led practices originally mooted by the NSC initiative. The initial plan was to have an International Think Tank, but that evolved to a focus on gaining advice on future investment from within Aotearoa New Zealand:

*"I'm one these people who think International Think Tanks have their place, but why should they be telling us what to do, and how are they going to know about what's good for New Zealand, and what's good to do here, and what our capabilities are?"*

After more exploration and discussion with leadership expert Lawrence Green, the idea of a Mission Lab was born where a small group of New Zealand leaders could think about what New Zealand needed. Once the concept of staying locally grounded was agreed to, the Leadership Team worked to determine exactly what such an event would look like and what it needed to achieve:

*"So then we had to think, 'Okay, what the heck is a Mission Lab?' One of the key things was managing to get (the late) Rod Oram interested, and serendipitous approaches to various people to come and join us for that first one. Totally luck of the draw who happened to be in the room, but it was really key for us."*

How did they work? The Mission Labs were quite different to processes occurring elsewhere in the RSI system, and it was a big learning curve for all involved. Rod Oram was involved in the initial development and went on to facilitate both Labs, but it was largely based on the willingness of the Leadership Team, who supported the idea of doing new things and worked together to create a plan, as well as the attendees who trusted in an unknown process:

*"The thing is, it's not a defined process - it's a bit open and ambiguous. And for people like me, that's always a challenge, whereas for other people, that's right up their alley. But then if we translate that through to the developing Missions, we were trying to break people out of their pet project, and that ego of 'I know what I'm doing, supporting me is right,' to try to get more of a consensus around what should be done."*

*"I think this method of operating that SfTI set up was very powerful in that it helped bring in people who might not have focused on problems of national significance, and so it unleashed people's energy through the different ways of working."*

Attendees were taken through a series of thought exercises, often working in small groups and then reporting back to the whole room. The questions posed started at a very broad level around what was good for NZ Inc., and gradually funnelled down to specific but still high-level research mission areas.

## What did the Mission Labs produce?

The question of which topics and technical areas SfTI should be resourcing to best support support Aotearoa New Zealand's future high-tech economy led to several key themes and ideas being agreed. At an over-arching level, Lab attendees said:[3]

- We should be aiming as close to the cutting edge of emerging and exponential technology as we can;
- We should build on what we are already good at, including food and functional foods, forestry, and Indigenous knowledge and philosophies;
- Whatever we do, we need to start with the problems that need solving;
- We should think more holistically and temporally to bring together corporate, social, cultural and environmental, as well as legacy considerations;
- Whatever we do, we need to be the best in the world; and
- Better connections between researchers and the rest of New Zealand are vital.

This first Mission Lab produced four potential Spearhead Project directions: The Digital Marae/Whare, Intelligent Oceans, Robotics for Small Scale Production and Harsh Environments, and Personalised Value Chain. It was SfTI's task to then transform these ideas into research and outputs:

*"Then we had all these ideas and we had to think, 'What do we do next with these?' So then we had to develop the Mission Design process - we had to put meat around that. So that was a fun time. Trying to figure all this out and work out what the heck we were going to do was really probably one of the most productive times that we had as a Leadership Team. I think it started to cement for me: 'What does it mean to be Mission-led?'"*

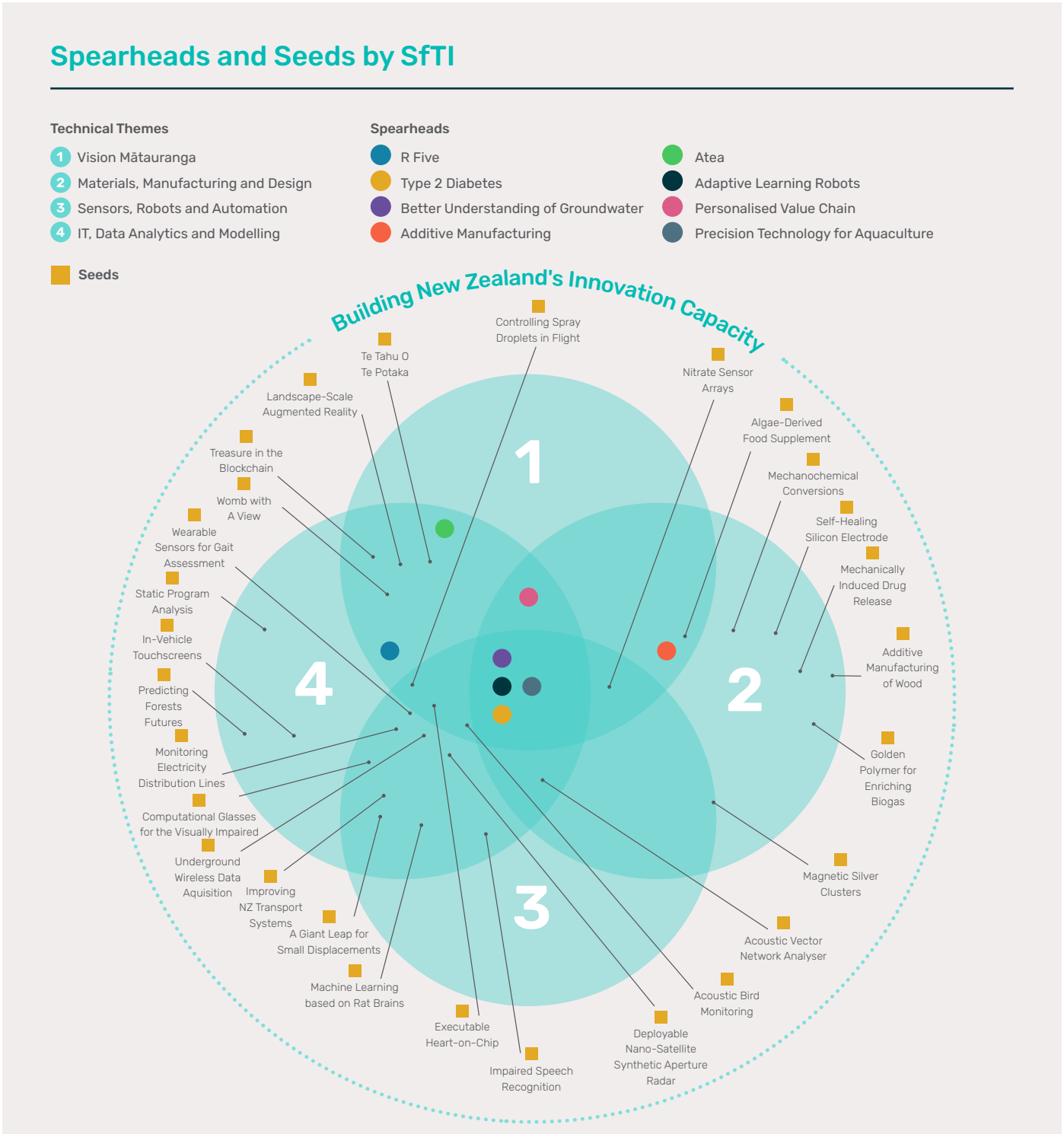
The first Mission Lab also generated the concepts of 'sticky' and 'stretchy' research:

*"So this is where the mantra of both stretch science and sticky science has been an important key driver of SfTI's research. It had to be stretchy - initially a five to 10-year plus window or challenge, but it's also sticky in that it had to be relevant to New Zealand and the benefit would need to flow to New Zealand."*

3. THE SCIENCE FOR TECHNOLOGICAL INNOVATION (SFTI) CHALLENGE Kia kotahi mai – Te Ao Pūtaiao me Te Ao Hangarau Industry-Led Consultation, Summary Report May 2017. (p19-21)

A second Mission Lab was held the following year, hosting 36 industry, Māori and government representatives, and this contributed more research ideas. By that time, SfTI's research ecosystem was already thriving, with seven Spearheads[4] underway, and two more in development,[5] as well as 28 Seed projects either completed or in progress:

### SfTI's Research Ecosystem Connections (2018)[6]




4. Commencing in 2016: Building New Zealand's Innovation Capacity (BNZIC); Inverting Electromagnetics; Medical Technology - Home and Community Care; Data Analytics Developing Industrial Decision Models; and Next Generation Additive Manufacturing. Commencing in 2017: Adaptive Learning Robots; and Precision Farming Technology for Aquaculture.
5. Personalised Value Chain (PVC); and Ātea.
6. SCIENCE FOR TECHNOLOGICAL INNOVATION KIA KOTAHI MAI: TE AO PŪTAIAO ME TE AO HANGARAU; MISSION LAB APRIL 2018. (p11)

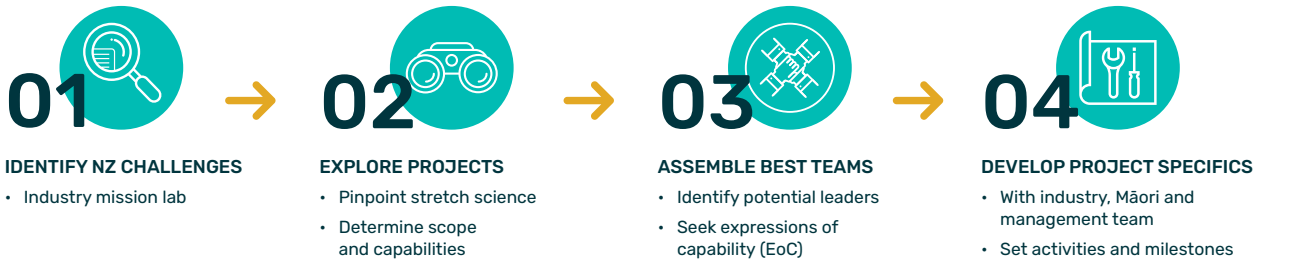
The intention had originally been to hold more Mission Labs, however, sufficient ideas had been generated from the first two to account for the remainder of SfTI's time and budget.

The evolving practice around generating new research projects from investigator-led, to group sandpits, and then to Mission Labs where industry and Māori highlighted areas for exploration has in effect flipped the usual process. This shift continued to evolve as the next iteration of project development occurred: best team formation and researcher collaboration.

"This was an avenue where Māori could have realistic input into technology that's being undertaken as opposed to: 'We'll create all our technology and then we'll go and ask Māori what they think about it', which is pretty much how things were going. I thought: 'These guys are going to have a chance to work with Māori first and then decide where the tech is going to go'."

# Spearhead Development and Research Process

SfTI's Spearhead projects were developed in partnership with industry and Māori in a two-phase process. First, the two large Mission Labs were held (in 2017 and 2018) to identify high-level technology project directions, and then refined through a 'Mission Design' process. The process as described below was evolved over time as SfTI continued to learn and adapt with each subsequent round of Spearhead development, learning what worked best as time went on.




## STAGE 1 - MISSION LABS AND MISSION IDENTIFICATION

SfTI held two large scale facilitated Mission Labs which brought together leaders from industry and Māori organisations to help identify high-level Missions for SfTI to pursue. The research directions selected had to have the potential to support the next step change in our economy, and explore opportunities that New Zealand can exploit in the hi-tech sector over the next 10-20 years. And they needed to be sticky (relevant to NZ) and stretchy (complex and challenging).

## STAGE 2-4 - COLLABORATIVELY DESIGNING AND REFINING SPECIFIC MISSIONS

### Stage 2

After the Mission Labs, with a small stable of research directions selected, the SfTI team continued to consult with relevant stakeholders to more fully scope the Mission topic and identify the technological research that could support any subsequent research, as well as gauge interest from the research community.

### Stage 3

The next stage of Mission Design was to select and form best research teams to help hone the Mission into a Spearhead project. In order to ensure the research would be carried out by new cross-disciplinary, multi-organisational teams, SfTI put out a Call for Capability where interested researchers would communicate their skills, interests and experience, rather than a proposal for the broad research question posed. This was a completely novel practice not seen elsewhere in the RSI system.

### Stage 4

This stage involved the Researcher Workshop where a group of selected researchers attended a facilitated workshop and then collaborated together to develop more defined research parameters.


## STAGE 5 - LAUNCH PROJECT

From there, once the SfTI Board approved final proposals, the Spearhead projects were launched.

## STAGE 6 - MANAGE AND PERIODICALLY REVIEW

The progress and health of a Spearhead project was measured against key milestones (critical steps) through a combination of six-monthly reports and online performance tools. SfTI recognised that not all research would go to plan, so where necessary a pivot could be negotiated to ensure the desired research outcomes were achieved.

A Science Quality Review was also carried out on all projects by an independent panel of local and international science experts to provide assurance to the SfTI Board that each Spearhead was meeting SfTI's goals of 'sticky' and 'stretchy' research. The Review typically occurred around the middle of the five-year research phase, and actionable feedback was provided to all teams.

## STAGE 7 - PROJECT REACHES GOALS

SfTI's Commercialisation Development Manager was available to work alongside Spearhead leaders and relevant technology transfer offices (TTOs) to guide research achievements towards investor readiness and/or economic impact.

## STAGE 8 - FINISHED

SfTI was a collaborative community that stayed connected with researchers after a Spearhead project had finished, for example, through leaving the door open to participate in further research, collaborate with other teams, or join select Capacity Development events.

## B. COLLABORATING

**"Being Mission-led is about going out to try to solve a big problem for New Zealand or take advantage of an opportunity for New Zealand. But the real value is creating that best team environment."**

Following the Mission Labs, SfTI Leadership realised they would need a Mission Design process for researchers because they had not been integrally involved in the Mission Labs. **Researcher Workshops** were held to start refining Spearheads, and these were attended by researchers as well as industry and Māori representatives who maintained an interest in a particular topic area.

As an example of process innovation, rather than asking researchers to pitch individual proposals based on Mission Lab outputs, SfTI sought *Expressions of Capability* for interested individuals to indicate what skills and experience they could contribute to the proposed project area. Based on these submissions, researchers were invited to the workshops as appropriate.

Mark Buntzen (The Distillery) was one of the Researcher Workshop facilitators who developed a bespoke process for SfTI. Essentially, the workshops had to do several things simultaneously:

A. Give participants the opportunity to be heard and feel heard in terms of their ideas and potential contribution.

B. Prevent people from pursuing their own agendas and pet projects at the expense of the Mission.

C. Obtain a range of information that would help the SfTI team make decisions on whether or not to move the new research forward:

   a. Problem statements – what would the subsequent research be seeking to address?

   b. Match capabilities brought by participants with the capabilities required to solve the research challenges under consideration.

   c. Identify potential team makeup in terms of technical expertise, experience, and personal attributes.

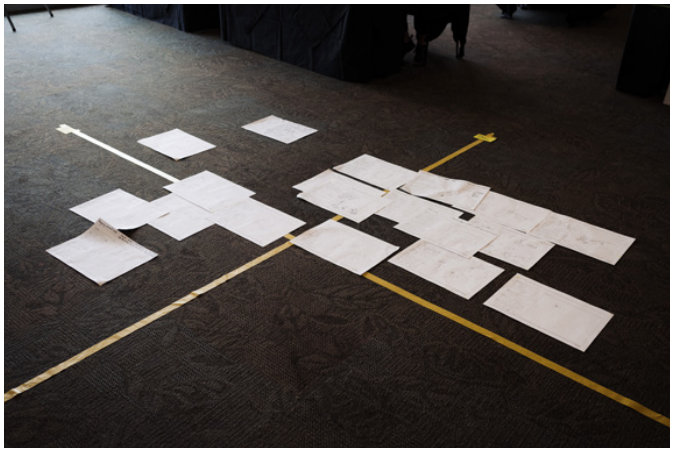
D. Ensure that the process felt neutral and objective to the participants. The 2x2 sticky-stretchy floor matrix was used to achieve this, which worked because it was a transparent and easily understandable tool.

The workshops were arranged so that people could offer project ideas early on in the process, but they then had to interact with others and their ideas because it was a social situation. This human interaction also allowed SfTI leaders to observe how people behaved, what positive contributions they made, and in particular, what potential they had to be part of one collaborative research team:

*"People had to be aware of the group, and they had to listen and negotiate."*

This process is unique within Aotearoa New Zealand's science and research system, which is typically highly competitive and seeks proposals from individuals and pre-formed teams. In contrast, team formation and proposal development for SfTI's largest projects was a negotiated process:

*"The Expressions of Capability really shifted the dial away from pet projects, and also the fact that you didn't have a track record because anybody could come to the Mission Design process. And Mark Buntzen was also quite key in helping us design the Mission Design process."*



*"This method of developing programs and projects where you get a group of people focusing on a problem of national significance has been really, really positive. SfTI was not asking people to come along with their pet idea that they want to get money for, but they're coming along with the capability and knowledge that they bring, and then discussing how can all of this capability and knowledge be brought to bear upon a problem that's got to be solved. And that is a completely different way of doing things, and it's extremely powerful."*

So, it is fair to say that this process was foreign to many who had not experienced it before, and some researchers were wired to promote their own ideas. Nevertheless, the process "*has helped people recontextualise their work within a larger whole, and in terms of purpose.*" SfTI was able to oversee formation of teams who could prove their willingness to collaborate and could bring the 'best' capability from across the country.

So, if the Mission Labs were about defining research areas for impact and meeting the priorities and aspirations of industry and Māori, essentially high-level collaboration, the Researcher Workshops were an example of practice-oriented collaboration. While this was an experimental process, the research community rose to the challenge and were changed in the process.

### What was the next step after the Researcher Workshops?

Observing how people worked together at the workshops informed who was invited into the final research team to carry out the post-workshop task of collaboratively writing a proposal to form a new Spearhead.

*"That's what I call the alchemy stage. That's really hard to pin down. And that's where the Leadership Team was really important in terms of thinking about who gets what we're trying to do."*

*"Iteratively and collaboratively, you get a better proposal. This whole process of conversation takes place, and you may find that your view of what it is you want to do evolves. 'What is it you're trying to achieve?' 'What is it you need?' It's effectively a hui, isn't it. And you never resolve something like this in one conversation, things mature."*

Part of this work involved, for example, developing a new template for proposal writing. "*We emphasised the things that were important to SfTI and not in the other standard proposals because we just had this flexibility to be able to build it the way we wanted, and in the way that would serve the Mission. That was really key, and it set the tone or the foundation for everything that's come since then.*"

In practice, working in such a truly new, inter-disciplinary team was a challenge for some, however SfTI provided support for researchers throughout this journey.

*"Our process for bringing those new teams together didn't allow the status quo. Again, we picked leaders to try and bring those proposals together, and to bring groups from across institutions together. And some of the historically powerhouse researchers, I don't think were in that space - they were too much into their own work."*

In terms of creating budgets for these new projects, SfTI normalised the practice of purposefully funding relationship development. Researchers were encouraged to itemise anticipated engagement costs and factor that into budget decisions, and the hope is, even after the Challenges come to a close, those individuals will continue to do so:

*"What is it going to cost you to go and meet with Māori organisations. What is it going to cost you to have them fly down to meet with you. If they start to actually do some research activity with you, even as a key stakeholder, you fund that as well. You fund koha, you fund catering costs, whatever it is. Researchers were starting to do that and building these costs into their budgets. If you've done it once, you do it next time."*

### What changes have there been in researcher behaviour?

Those involved with SfTI, and some other Challenges too, recall a change in how researchers behaved over time - from the early competitiveness, towards being more cognisant of the overarching Mission and having a better appreciation for what others could bring to research endeavours. Many of those interviewed for this legacy document remember going through that process themselves, and they certainly observed it in others. As one senior researcher described it, over time they became more focused on the bigger picture:

*"So what ended up happening for me was that I got a little bit seduced by how much potential good we could do for Māori across multiple areas. And then I came to realise, 'Stop worrying about your own personal research interests, and then focus on all of these other researchers that SfTI can fund and allow that to happen and open up opportunities.' So I realised it was bigger than what I personally want done."*

And another noted: "*[After a while] everyone was actually going towards the same thing. It wasn't about their patch or their university or their researchers, or MBIE's control or Callaghan's control, or the Board wanting to prove themselves or whatever. Everybody was actually really driven towards what we were trying to achieve. So everybody collaborated really well and it just worked so well.*"

Other researchers have also appreciated the experience of working with so many different people, especially those from within other domains, something many of them had not had the opportunity to do elsewhere in the RSI system:

*"Let's bring in industry, let's bring in Iwi, let's bring in the Kāhui, bring everybody and talk about it. I think that willingness to try some new stuff in terms of what collaboration actually means is probably one of SfTI's biggest successes."*

*"For me it seemed like it was breaking down the barriers of researchers working within their own institutions. It was more like: 'Here's an issue, let's solve this issue, no matter where or with which institution you are based'."*

*"For me, SfTI's legacy is not just the people, but the ability to engage with people and to share projects and be comfortable working with those people at another University or those people somewhere else, and removing that barrier. And so ultimately I think for New Zealand, it's better science. We're creating better science."*

As one Spearhead Leader has said, working within the SfTI Challenge has allowed their research team to genuinely collaborate:

"What I'm most proud of is that SFTI have allowed us to pull together a team that wouldn't have otherwise formed. And what that's done is allowed us to create and to innovate in ways that we wouldn't have been able to before. What we've learned is how to collaborate. And what I mean by that is collaborate in the truest sense of that word. I think we throw that word around a lot, but at the core of that is trusting relationships, and the ability to have young people working with old people, experienced with not so experienced, and learning from each other."

Researchers have shown themselves to be keen to collaborate. However, outside of the NSCs, the system can fail to support relationship-building approaches. According to many of those interviewed for this legacy document, there should be more incentives and resources for collaboration, and this has never been more true than today with the large-scale, complex problems the world is dealing with, such as biodiversity loss. In these cases, limited short-term funding is not going to lead to realistic solutions; interdisciplinary, multi-party collaborations are the only way forward. As one leader explained, "*What we really want with collaborative Mission-led work is for researchers to be working on things that are important but fairly intractable without collaboration, because we're not going to solve climate change with a half a million dollar proposal over three years*." Clearly, collaboration is a vital aspect of being Mission-led.

## C. VISION MĀTAURANGA

Genuine collaboration is only possible in Aotearoa New Zealand when researchers understand the value of, and are committed to, partnering with Māori. They also need the skills to do so, and to be properly resourced by their organisation. Vision Mātauranga (VM) provided a framework to support researchers in this direction, and the Kāhui Māori and VM Theme Leaders have driven Vision Mātauranga across a number of touch points to ensure a Te Ao Māori perspective infused across research activities.

Specifically, the team created a model for VM assessment, maintained a close relationship with SfTI Leadership, successfully advocated for higher funding levels, informed capability training, pushed for Māori leadership in research projects, contributed to the advancement of Māori Data Sovereignty, supported the Rauika Māngai, and strengthened SfTI's partnerships with Māori.

### Vision Mātauranga

A New Zealand government science policy put in place in 2005, Vision Mātauranga's purpose is to unlock the science and innovation potential of Māori knowledge, resources and people for the benefit of all New Zealanders. Within SfTI, Vision Mātauranga was one of the four Research Themes, and has guided researchers on how to integrate western science with mātauranga Māori (knowledge) to explore new opportunities for building prosperity. SfTI aimed to be an international exemplar in this area, for example, by encouraging more Māori to access the hi-tech research sector to fulfil their economic and wellbeing aspirations.

Vision Mātauranga planning and practice within the Challenge was guided by a set of tikanga (principles):

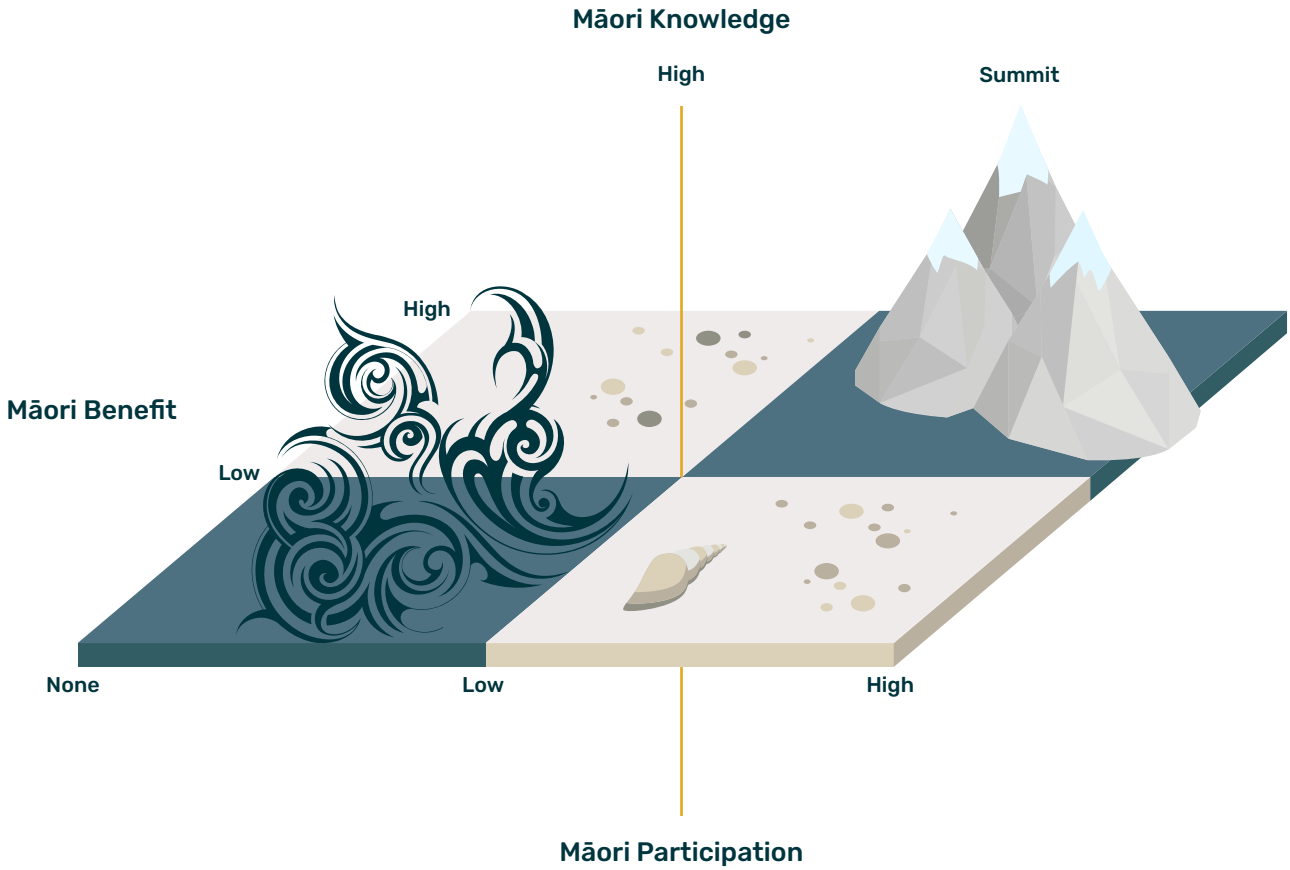
- kia kōtahi mai – holistic consideration of society beyond the Challenge
- rapua te pae tāwhiti atu – looking beyond the horizon
- kia whakapakari mai – developing and strengthening people, particularly the next generation
- tūhononga – integration of people and processes
- mana motuhake – an independent and self-determined approach
- mana whakahaere – empowered leadership.

### A VM assessment model.

The Kāhui Māori developed *Te Tihi o te Maunga*, which highlights three pou as vital for research to be considered VM-led. These three elements are Māori Knowledge, Māori Participation and Māori Benefit. As a model of assessment that fed into Challenge activities, it provided "*a framework, conceptualised as a journey, that maps projects from having little or no Māori innovation (viewed as landing on the shore), to incorporating some potential for Māori (arriving at the base of the mountain), to high levels at the summit where science and mātauranga innovation occur*."[7]

7. Amoamo, M., & Ruckstuhl, K. (2021). Kāhui Māori; Distinctive Leadership in Science and Technology. In M. Amoamo, M. Kawharu, & K. Ruckstuhl (Eds.), *He Pou Hiringa; Grounding Science and Technology in Te Ao* Māori (pp35-54). BWB Texts. (p44)

## Te Tihi o te Maunga




"*Willy-John [Martin] and the Kāhui* Māori did a very good piece where they defined some criteria which better enabled assessors, even if they weren't Māori, to judge whether a project had strong or weak Vision *Mātauranga alignment*."

*Te Tihi o te Maunga* was used to formulate *Te Aromatawai*, an assessment tool that uses a series of questions to guide Seed research funding decisions - it created a process that ensured genuinely VM-forward projects were given due priority. Vision Mātauranga proposals and research were carefully reviewed by leading Māori experts in the field and then contracted projects were overseen by experienced Māori academic mentors.

*"Our Theme Leaders in particular insist that Vision Mātauranga is considered in every proposal. So you can't get away with just saying, 'No, not relevant,' unless you say why it's not relevant. And that is an expectation that was followed up on."*

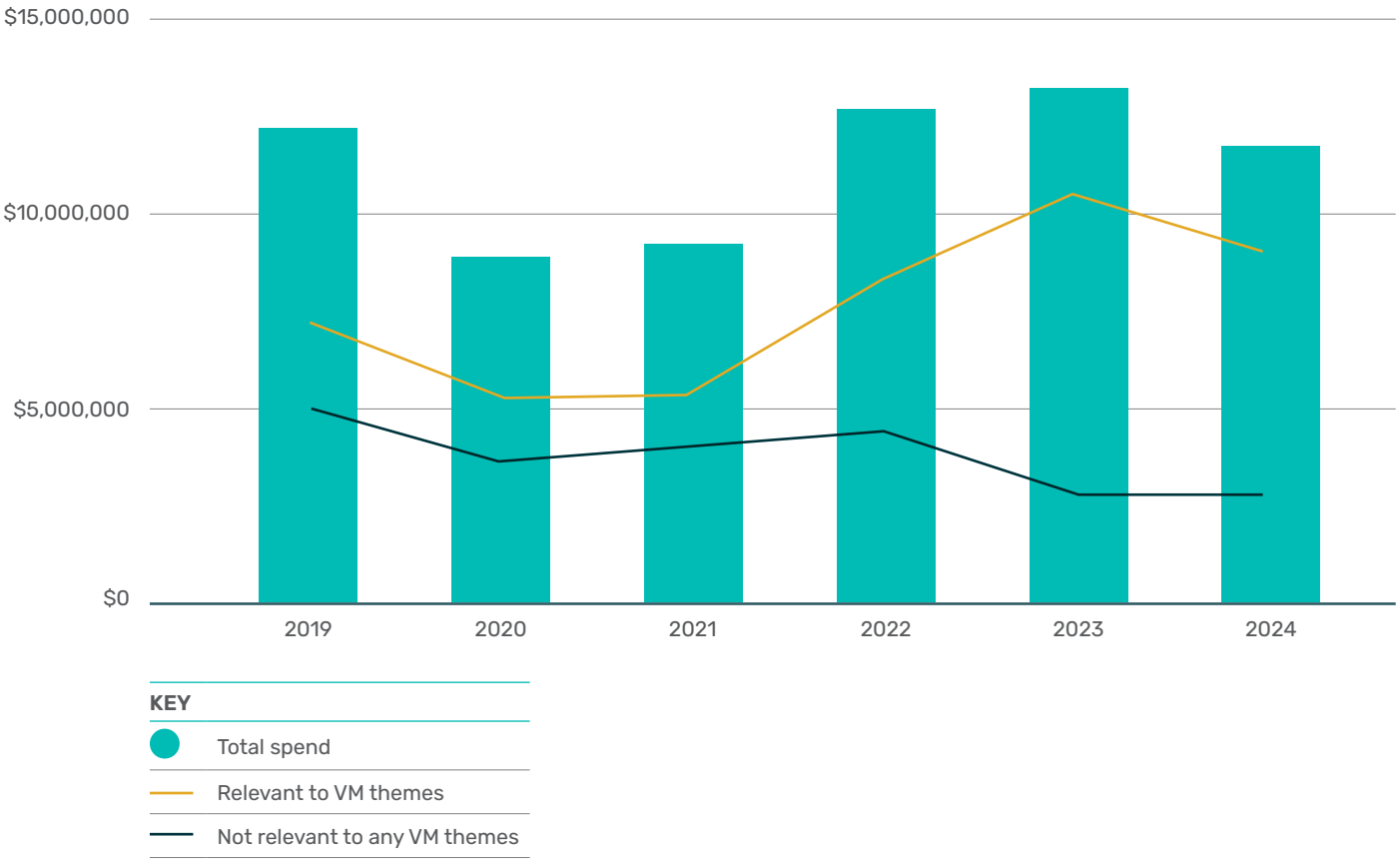
### Relationships with the Leadership Team

Vision Mātauranga was championed by the entire leadership group as they sought advice from the Kāhui Māori to ensure a Te Ao Māori view was embedded across planning, decision-making, funding and research. There was a great deal of overlap between the Kāhui and Leadership Team, with the Director and VM Theme co-Leaders sitting inside both groups.

### More funding for VM research

Resourcing was another important factor that SfTI got right by appropriately funding Vision Mātauranga activities and capability across the Challenge. For one, guidance was provided to researchers working within this theme about what constituted VM research, and a minimum 20% of contestable Seed funding was ring-fenced for VM-aligned proposals, later increased to 25%. SfTI's funding of VM-led research continued to increase over time, and in fact, during the second tranche, overall investment in VM-relevant research was twice that of research that did not meet the VM criteria: $45.2m v $22.1m.

## SfTI Investment in Tranche 2 Research




### Enhancing capacity

SfTI provided researchers with capability training to incorporate Vision Mātauranga into their work, and to build purposeful and mutually beneficial relationships with Māori. This was identified as one of the high impact Capacity Development areas in both of SfTI's Capacity Development Reports. Developing cultural capacity can be achieved via different methods, many of which SfTI has employed, including:[8]

- Resourcing researchers to attend national hui on topics of significance to Māori such as the two Māori Data Futures Hui and the Federation of Māori Authorities (FOMA) Conference.
- Enabling researchers to attend workshops, for example, about Māori and Indigenous research, the Māori Economy, or the history and impact of the Wai 262 claim, and implications for research practice in the current time.
- Supporting researchers' self-identified learning opportunities, for example, te reo language papers or attending lectures by Māori academics.

Researchers and leaders reported a number of benefits as a result of attending VM upskilling, including greater understanding of the Vision Mātauranga policy, which they could then draw from to inform relationships with Māori communities to create benefits with and for those communities. There was also a better appreciation for Te Ao Māori and the Māori economy, and new networks and partnerships with Māori businesses and organisations were developed, with researchers reporting increased confidence with those engagements

### Increasing Māori leadership

VM projects were strongly encouraged to have Māori leadership where capacity and capability were available, and where this was not possible, Māori partnership was enabled. There have been several SfTI projects that were led and co-led by Māori and dedicated to realising Māori aspirations.

8. Science for Technological Innovation. (2022). *Interim Capacity Development Report: Accelerating Science Innovation Through Human and Relational Skills Development.*

One of these projects was *Ātea*, which worked to create a virtual, digital space in which Māori knowledge could be created, articulated, interpreted, interrogated and built, and that also served as a place where Māori could connect, share, create and develop reo, whakapapa, culture and identity as Māori for Māori.

*Te Tātari Raraunga – Analytics to identify and connect successors to whenua* was another which, in partnership with Parininihi ki Waitotara (PKW), created smart data analytics tools to help find rightful Māori shareholders to connect them to their land. Yet another was *Te Pā Tūwatawata*, hosted by the Data Iwi Leaders Group, which is well on its way to creating an iwi-Māori designed, owned and operated data repository network.

*"I think SfTI's opened up a whole lot of opportunities and a whole lot of doors for Māori to lead and engage. Has it been perfect? Well nothing is perfect, but it's been pretty awesome. It's important that we learn from what we have done and achieved, and also not achieved, so we can improve into the future. It's a massive learning curve for us all, the leaders, researchers, and the communities."*

## Advancing Māori data sovereignty

This is a topic of particular importance to Māori, but in the early years of the Challenge, there was far less activity than there is now. SfTI co-hosted two Māori Data Futures Hui with the Data Iwi Leaders Group, Te Hiku Media and Te Herenga Waka - Victoria University of Wellington.

The first hui was in May 2018 at Te Herenga Marae, Victoria University, Wellington, and brought together Māori data thought leaders, iwi and hapū representatives, Māori researchers and practitioners, rangatahi, and data specialists. Presenters and delegates explored a number of questions related to: data within a Māori context; key issues and challenges for Mātauranga Māori protection; ensuring appropriate tikanga around digital guardianship, data sovereignty, data security, and respectful use.

A second hui, held at Te Aurere (at the request of the late Tā Hekenukumai Pūhipi), focused on protection for Māori data and knowledge as intellectual property (IP). While attendees discussed what the ideal future for Māori data would look like, they were also asked to consider how to protect Māori knowledge in the context of Māori data development, so that it may be used in the right way and by the right people, to create an ideal future.

Many delegates at the first hui were new to the indigenous data kōrero and benefitted from presentations from a panel of Māori data experts, and there was good support for including rangatahi inside the event. In contrast, the second hui invited presentations from a wider range of (primarily Māori) speakers who covered a range of topics including IP law, genomics, language preservation and research. There was also a guest from Australia who spoke about information supply chains, and a local haukāinga who laid a service delivery lens onto data.

These events elevated the wider kōrero about Indigenous Data Sovereignty in this country.

## Supporting the Rauika Māngai

During Tranche One, SfTI actively supported the formation of the Rauika Māngai, an assembly of senior Māori representatives from across the National Science Challenges and Nga Pae o te Māramatanga. The Vision Mātauranga Leadership Hui of 2019 was a partnership between the Rauika Māngai and SfTI, which bought together over 100 individuals at the forefront of VM, and formed the basis of the influential *Guide to Vision Mātauranga; Lessons from Māori voices in the New Zealand Science Sector,* which has inspired change across the research sector.

## Strengthening partnerships

Guided by the Kāhui Māori, SfTI has formalised a number of partnerships with Māori organisations including Te Hiku Media, FOMA, and the Data Iwi Leaders Group.

*"Through the VM Theme we have taken a really deep dive to think about our Māori communities - and that includes businesses, iwi communities, hapū and enterprises - and how they can advance their own aspirations through science and technology and engineering. I guess the biggest change that I have seen and the biggest impact has been the way that our Māori communities in particular have embraced science and technology."*

*"There's been opportunity for Māori to do research as Māori. Not so much Māori to do research in what the government wants, or a commercialisation-specific aspect. But it's for Māori to be able to sit down and say, 'Okay, now what is really important to us as Māori? And how can we solve that in a Māori way?' So SfTI has enabled that to happen."*

### What happens after SfTI ends?

With all eleven of the National Science Challenges coming to a close, researchers have been considering what comes next for Vision Mātauranga. The final SfTI All of Researchers' Workshop in late 2023 was an opportunity to explore this question. An expert panel made up of SfTI leaders, Pauline Harris (VM Theme co-Leader and member of the Kāhui Māori), Nancy Garrity (Kāhui Kaihautū) and Hēmi Whaanga (Ātea Spearhead Leader) agreed that SfTI had presented many opportunities for Māori researchers to approach research more authentically, for example, in being able to elevate social aspects of their work and/or collaborate with Māori partners. They also noted that they were witnessing non-Māori researchers placing more care and effort into forming relationships with hapori Māori. Losing the SfTI platform is a serious concern, however, they hoped that researchers would take on the challenge of continuing the momentum already created.

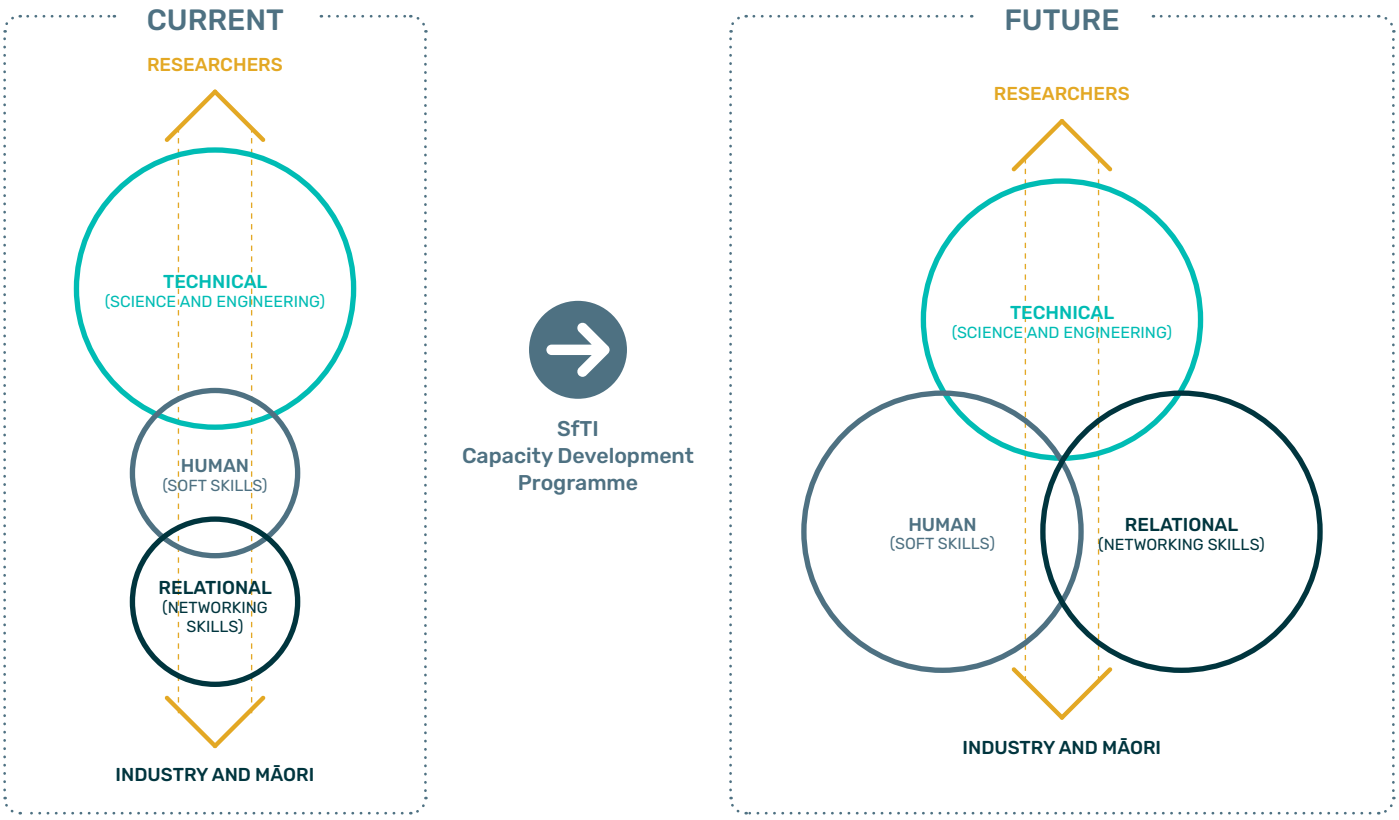
## D. ENHANCING CAPACITY

**"Other than Vision Mātauranga, Capacity Development will be the thing that probably has added the greatest value to the research system because the researchers will carry that in their knowledge and their experience and into what they learn beyond SfTI. So when SfTI comes to an end, those researchers are still part of the system. And having done it once, they'll be happy to do it again."**

As noted above, researchers need particular skills in order to collaborate with each other, with industry and with Māori: SfTI's Capacity Development (CD) Programme offered researchers the opportunity to develop those skills.

A key element of SfTI's Mission was to *enhance capacity*, and it chose to focus on: **Human Capacity**, related to influencing, managing, collaborating, and communicating with others; and **Relational Capacity**, which underpins the ability to make and maintain networks with industry, Māori, and scientists across multiple disciplines. Bringing these skills together with new **Technical Capacity** was seen as the ideal way to help researchers achieve Mission-led research impact, now and into the future. This focus made SfTI unique in the National Science Challenges in that its Mission was explicitly behavioural as well as technical in orientation.

## How SfTI Conceptualised the Three Capacities Needed for Collaborative Research




The Challenge very succinctly described its novel approach to capacity early in Tranche One, using two Venn diagrams to illustrate how capacity was viewed traditionally and how it should ideally change:

*"The Venn diagrams really helped to convey: Where we are now and where we want to get to. It helped people to understand what SfTI was trying to do. Yes, we know technical capacity is going to improve, it's probably going to improve anyway, and we want to accelerate that. But it's those two other areas that we really need to develop much more effective ways of lifting."*

*"It basically emboldened us to be more assertive with thinking about our community: How are we going to enhance their capacity? Whose capacity do we need to enhance? It fed into quite a lot of consequential decisions."*

Conceptualising capacity in this way served to catapult SfTI away from simply being another funder of research that made grants to those already well-resourced, or which continued to regard non-technical skills as significantly less important in producing excellent research. Instead, the Challenge was able to experiment with how best to engage with early career researchers, for example, who would benefit most from capacity development opportunities. It also created space for elevating the importance of collaboration skills.

A particularly impactful aspect of the Capacity Development Programme was that its funding was ring-fenced so that researchers did not have to make the choice of whether or not use research budget for CD. And more than that, it was a free opportunity for academics to learn things they may not otherwise. There was also an expectation that everyone in the SfTI community should take advantage of the opportunity to participate in CD training, and those who did (just over half of all researchers), benefitted significantly:

*"We've probably grown a really strong set of new leaders coming through, particularly those on the science leadership program. It's very hard to quantify, but I think we've enhanced people's capacity along those multiple dimensions, such as Vision Mātauranga, leadership and collaborative research."*

Another positive dimension of the CD offering was the mix of a curated list of offerings, such as VM-training, science leadership, and Rewa Ake, supplemented by the ability of individual researchers to nominate other events depending on their learning needs. The programme aimed for a high level of flexibility and responsiveness.

There were two levels of Capacity Development too: the *informal learning,* gained for example through mentoring received from the Kāhui Māori and Theme Leaders; and *formal, structured* CD offerings such as media training.

Reece Moors, Katharina Ruckstuhl and Willy-John Martin were key in informally building the capability of the Leadership Team and Board around things Māori. Cultural competency amongst those leaders was important for many reasons, for example, so the Kāhui Māori would not have to defend their recommendations or initiatives.

Over time, the concerted approach by those key Māori personnel worked as intended: *"The non-Māori Board members, and non-Māori members of the senior Leadership Team would jump in [to support] and say, 'Hold on, what are we doing with Vision Mātauranga here and here and here and here?"* The cultural development architects could sit back and watch this advocacy happen:

*"We were able to bring people (non-Māori) along the journey in a very subtle way to the point where they were actually our (Māori) greatest promoters, guardians, defenders of the faith."*

*"They made it easy for the stale white males of the world to understand Mātauranga."*

The formal CD programme activities were categorised into three types according to the processes they supported:

1. **Priority-sourcing**: Ensuring that research questions, approaches and investment aligned with industry and Māori aspirations;
2. **Collaborating**: Empowering multi and interdisciplinary teams to collaborate; and
3. **Implementing**: Getting ideas out of the lab and into the market where their social and economic benefits could be realised.

Where Tranche One had a particular focus on Vision Mātauranga upskilling, Tranche Two saw a swing toward a more comprehensive commercialisation offering, and leadership remained popular throughout the life of the Challenge.

### Priority-Sourcing - Cultural Development

There are relatively few senior Māori researchers in physical sciences and engineering and this had implications for the Challenge in terms of structure. For example, co-leadership could not be put in place for every project as it had been in some other Challenges because there were not enough Māori researchers in the SfTI community. With this in mind, SfTI adopted an alternative direction, that is, it carefully and purposefully developed cultural capacity of researchers, the Leadership Team and the Board so that where there were only non-Māori leaders, sufficient support and other Māori relationships were put in place.

*"I think that engagement with community and stakeholders and especially Indigenous communities and stakeholders is a real strength of SfTI. I think it's just normalised for the researchers and so it becomes less tokenistic, less about box ticking."*

Having senior researchers and managers develop their cultural understanding and practice has been significant. Several members of the Leadership Team have talked openly about their own cultural development journeys, something that was appreciated by their Māori colleagues:

*"It's beautiful what they've been able to contribute, and it was beautiful to see some of them had made a real, significant difference to Māori."*

*"Steven MacDonell got up and talked about the benefits of Mātauranga Māori in research. And it was cool how those two (Stephen and Don Cleland) talked about it rather than a Māori person getting up and talking about it. And when they talked about it, you could see they really believed what they were saying. They really found value in Mātauranga Māori in quite technical areas of research."*

## Collaborating - Leadership

Leadership was one of the most popular CD offerings from SfTI, and is particularly important in larger, multidisciplinary research teams and those collaborating with external partners - the ability to foster positive group dynamics and build relationships are two cornerstones of Mission-led research.

The Science Leaders Programme (SLP) was a culmination of learning from previous leadership offerings: the one-day Relational Leaders Programme, individual coaching, and the three-day intensive Emerging Leaders Programme. Having observed how scientists responded to this area of skill development, programme designer Lawrence Green was able to zero in on what was really important: "People were struggling with the question of influence, struggling with personal confidence and with leadership intelligence, or bringing their best smart thinking to the leadership problems they were facing;" the SLP was developed with these very challenges in mind.[9]

## Implementing - Commercialisation

Commercialisation-focused Capacity Development helped researchers to think about how to make their research more commercial, through researching potential markets or managing Intellectual Property (IP) concerns, for example. In addition, it assisted those with a more purely academic outlook to become more comfortable in this space and to see how their research could become more commercial, even if this might eventually be progressed by others:

*"It helped them change their mind-set. It enabled them, when they're doing their fundamental research, to then start thinking at some point: 'How might this have impact or commercial benefit?' And then think about what the next bit of science might be. So future research could be determined more by that commercial pathway than it is just by, 'Oh, wouldn't it be interesting to do this,' which is perhaps the more academic path."*

Commercialisation Development Manager, Deborah Crowe, says that Technology Readiness Level 3 (TRL3)[10] is about the time researchers can usefully begin to work towards commercialisation. This may involve socialising the research to interested parties through conversations, gaining a better understanding of the problem/opportunity, and/or exploring market potential. These early activities can inform subsequent funding applications and business case writing, as well as decisions around business model and market approach, for example.

The latter part of Tranche Two was focused on what happens beyond SfTI, particularly for those moving closer to commercialisation, which was a sensible evolution. In this regard, KiwiNet was a useful partner for the Challenge because it could take researchers forward on their journeys after SfTI concluded.

## What were the Impacts of Capacity Development?

As a result of SfTI's Capacity Development Programme, a number of positive impacts have been experienced by participants:

- enhanced personal confidence
- improved ability and willingness to seek out others' perspectives and to integrate subsequent new understanding into the research
- increased networks inside and outside the research community, and
- guided practice of new behaviours cementing behaviour change.

Those interviewed for this legacy report agreed that the rest of the RSI system would ideally have similar offerings:

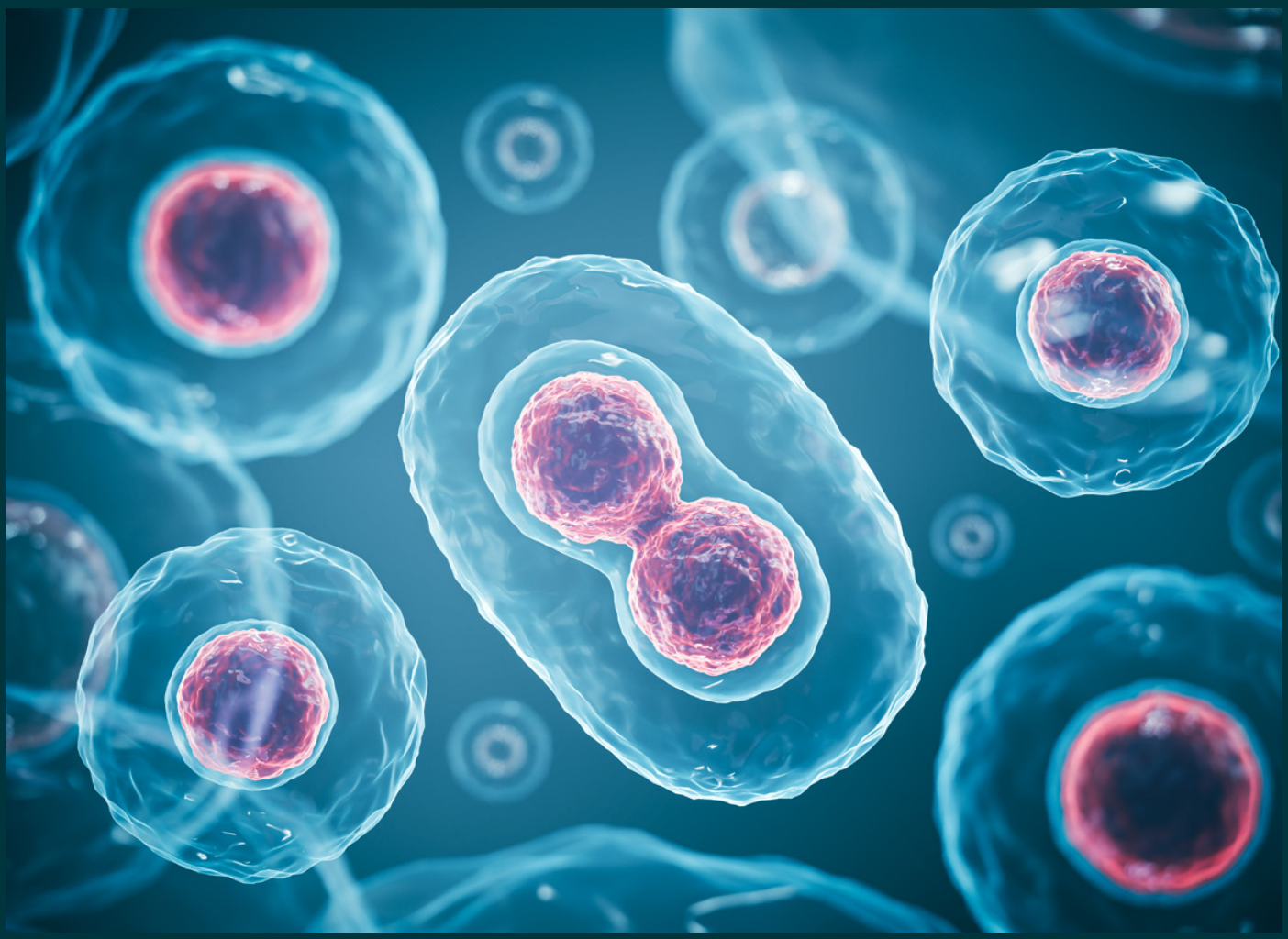
*"There needs to be that capacity development piece because how are you going to grow good researchers if you're just focusing on the research and published papers? They've got to be better communicators, better entrepreneurs and better public partners."*

While the SfTI community did report instances of non-technical training available through their institutions, there are no other programmes as comprehensive as SfTI's.

9. Science for Technological Innovation. (2024). *Final Capacity Development Report; Accelerating Science Innovation Through Human and Relational Skills Development.*

10. TRL is a metric used for describing technology maturity. TRL3 is defined: Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.


University of Auckland
Speaker



# 4. Innovating Research

In Tranche One, SfTI employed a matrix of Portfolios[11] and Research Themes.[12] Each of the five Portfolios had a Spearhead project sitting within it, but this was later considered somewhat confusing, and so the Portfolios were discontinued and Themes came to the fore. In 2016, the first Seed funding round was launched, resulting in ten projects being contracted, and in the following year, a further 18 projects were funded. Moving into Tranche Two, each Spearhead and Seed project was required to relate to at least one of the Themes.

Over its ten years of operation, SfTI endeavoured to be innovative in how projects were developed and managed, with some very interesting practices being refined. These include creating novel processes for developing and mentoring small high-risk Seed projects, simplifying research administration practices, pivoting and discontinuing projects, and experimenting with the Concept-Knowledge (C-K) Method to form teams:

*"There have been some major breakthroughs from SfTI, and I don't think it's just the money. It's how the money has been spent, trying to bring those stakeholders in, trying new ways to engage researchers, Seed funding for early career researchers, trying to build it from the ground up. One thing we kind of forget is that SfTI is doing all these amazing things that didn't previously exist. So we've got to remember that there's been a lot of bang for the buck. It does show what could be achieved if you've got the right people and the right project and the right resources."*

*"For me, the great value add of SfTI has been the ability to be innovative within a very complex system."*

## A. INNOVATION

"We had the ability to not just do things the status quo way as it's been done elsewhere, we had the ability to say, 'We don't have to do that.' We gave ourselves the license to try doing some things differently and we tried to build off what was good about existing systems, but always putting something, a SfTI tweak, on it or trying to prompt the community to behave differently."

### Process Innovation - Seeds

Seed projects were introduced during SfTI's second year via a smaller, competitive fund. Whereas the Spearheads were formed collaboratively and involved larger, more diverse teams, Seeds were smaller, high risk, technically complex and based on ideas developed by researchers themselves. They were funded for up to two years with a maximum of $200,000 per project.

Interestingly, even though the Challenges were considered innovative because of their collaborative (rather than competitive), Mission-led foundations, within this small pocket of contestable funding, SfTI still managed to develop novel processes for encouraging and assessing proposals, and for overseeing the research projects.

For example, several Theme Leaders launched a Roadshow after the first Seed funding round because of an uneven response from the research community. An overabundance of proposals related to *Materials, Manufacturing and Design*[13] had been received, but at the same time, few were *VM*-focused or sat within the *IT, Data Analytics and Modelling (ITDAM)*[14] Theme.

The travelling roadshow aimed to address the lack of proposals in those domain areas, as well as bring more underrepresented groups of researchers into SfTI, including Māori, women and early career researchers. Stephen MacDonell in particular helped people learn how to write proposals for digital projects, which eventually made SfTI an important funder in the digital space. It was interesting to see that it was possible to **actively change the composition of SfTI's portfolio of research** and the makeup of its community:

11. 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.
12. Sensors, Robotics and Automation; Materials, Manufacturing and Design; IT, Data Analytics and Modelling; and Vision Mātauranga.
13. This Theme was later renamed *Materials, Manufacturing Technologies and Design*.
14. ITDAM would later be renamed *Data Science and Digital Technologies*.

*"I really did wonder whether it was going to work. But we tried some things and got quite a shift in applications in terms of standard and the number as well. So I had some real doubts about whether we could move the dial through those sorts of initiatives, but we did shift the dial."*

The Seed **proposal assessment process** had something of a lighter touch. The assessment team decided to triage proposals into those that looked particularly interesting, those that were 'maybes', and a third group that would not be funded. There were more fundable applications than could be supported, so the eligible proposals were put into one of two (later three) ballot boxes - Vision Mātauranga, (later Early Career Researcher) and General - and selected randomly from there:

*"It was the fairest way, because at this phase you can go through word by word, little line by line through all these proposals trying to decide this, that, and the other thing, but you can't actually distinguish between them. You have to be honest about that. The real question is: 'Are they interesting or not in the end?' If you accept the fact that not all proposals lead to successful results, then you want to try to generate a system where there's opportunity for risk ... so there's also opportunity for reward."*

This in effect, demonstrated SfTI's acceptance of risk, and was an example of taking a portfolio approach that allowed for stretchy science:

*"The Spearheads were about bringing groups together that hadn't worked together. The Seeds were about: here's an interesting idea, let's explore it. And I think if you look at the impact [in the near term], the Seeds are probably having a higher hit rate in terms of the science going somewhere."*

Once their proposal was accepted, Principal Investigators received **mentoring** from Theme Leaders and members of the Kāhui Māori. Helping researchers develop and achieve appropriate milestones was one specific way this contact was helpful:

*"Our Theme Leaders worked really hard on making sure there were proper milestones, particularly with inexperienced researchers. This meant that when a proposal got funded, that wasn't the end."*

*"For a Māori researcher to have a senior Māori person ring them up and ask them how they're going, for example, Pauline [Harris] ringing them up, that's significant."*

### Process Innovation - Simplification

One practice experimented with across both Spearheads and Seeds was the simplification of various processes. With regard to funding applications, simplification served to reduce the workload for researchers and external partners without impacting the quality of research or relationships:

*"I actually think we got the number of words right down, and yet we got as valuable information as I've ever got out of much longer MBIE Endeavour bid documents."*

*"There has been a push across everything we do to make it as simple and as easy and low transaction cost as possible. And that goes through to contracting or if you have to change anything – any way of interacting with us, we try and make it as easy as possible. And I think we've got a reputation with the Research Offices as being one of the easiest Challenges to interact with. That's part of process innovation."*

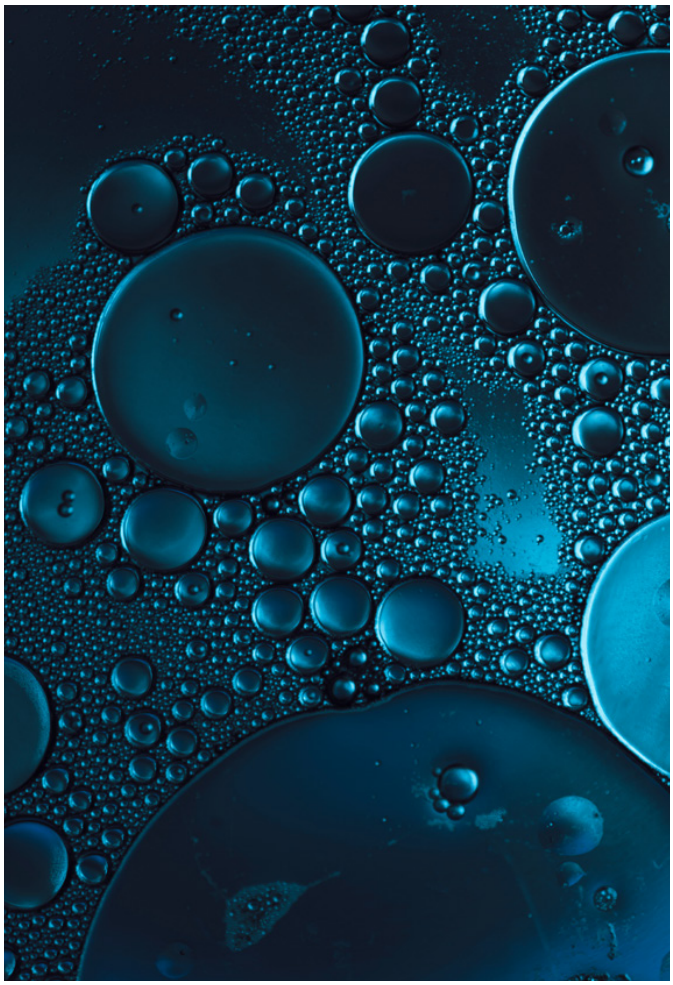
With regards to proposal assessments, it has resulted in a radically new practice for getting small amounts of funding into the research community to explore interesting new ideas, especially by early career researchers, without a high administration cost. Further, the Seed ballot system helped assessors make their evaluations more quickly and with less anxiety, and it helped researchers come to terms with not being funded because there was a small element of chance involved.

## Process Innovation - Pivoting or Discontinuing Projects

**"Our systems have to allow scientists the freedom to fail or pivot halfway through. That's something that the management team have excelled at. So proud of them for helping people realise it's okay to change. It's okay to stop putting bad money after bad money – that's not failure, that's research."**

Because the Challenge was more than simply a funder, it followed projects through, monitoring progress and checking in with research leaders along the way, management was always aware of progress and roadblocks. Not every project proceeded as planned, and SfTI had strategies to deal with this.

The practice of pivoting allowed SfTI to get better value out of projects because if the originally planned approach was potentially not going to work, then adjustments could be made towards something more likely to be productive, rather than stubbornly following the originally contracted research plan.



One example of a useful pivot from the point of view of SfTI leaders was the Rangatahi Spearhead. A decision was made to develop a Rangatahi Spearhead after one young social entrepreneur asked where the rangatahi were during the second Mission Lab. And so the process began - there was a Rangatahi Mission Lab in early 2019. The matter of how the voice of young people could be better represented in the RSI system, which was currently dominated by those aged over 40 years, was explored:

*"We looked around the room [at the SfTI Mission Lab] and felt a little disheartened that their research would retire with them in the next ten years. We thought that we, the next generation of business leaders, of policymakers, of social entrepreneurs and technologists, should have the opportunity to contribute our thinking."*[15]

15. Rangatahi Mission Lab Report (2019). Unpublished.

The event generated many potential research ideas, but the process of settling on a technical Spearhead project was not proving fruitful, even after a significant amount of effort and time had passed. There was an element of friction between the comfort with speed and risk favoured by the younger entrepreneurs on the one hand, and the technical parameters put in place by SfTI management on the other:

*"We were really struggling because we just weren't converging, we were continually diverging. It was never coming to a point where a project was going to emerge. And part of it was that the people involved weren't researchers, they were entrepreneurs and community leaders so they didn't know how to frame up anything of that technical nature. We got to a point where we said, 'This isn't working, we've got to do something different'."*

As a way of resolving the impasse, a member of the Rangatahi Team suggested smaller projects that could bolt-on to the existing Spearheads but be led by a young person. The SfTI team thought that was a brilliant idea. Principal researchers had to be less than 35 years old to be eligible, and an assessment panel made up of rangatahi helped evaluate project ideas. The initiative was a success, with one member of the Leadership Team saying, "*I actually think they did a much better job than our senior panels - similar circumstances, much more rigorous, and an absolutely great job of being inclusive*."

In this instance, although the Early Career Researcher (Rangatahi) Bolt-on projects (ECRBOPs) did not reach the same scale as a Rangatahi Spearhead would have, pivoting enabled an alternative route to bringing young people into the SfTI community to contribute to achieving the Mission:

*"We got some good projects funded and some good young people were supported."*

Sometimes a pivot was not enough, so SfTI was also prepared to stop projects altogether if they were not sufficiently aligned with the Mission, if they were too business-as-usual, or if they were not making enough progress. Making the decision to discontinue or pivot projects was always well-considered and tended to follow a science quality review process:

*"Taking our Mission achievement seriously meant we had to put a line in the sand with some projects."*

*"It sent a message that things weren't just locked in stone to continue forever."*

## Process Experimentation - Applying the Concept-Knowledge Method

As the Building New Zealand's Innovation Capacity (BNZIC)[16] research highlighted, solving big societal challenges through Mission-led research requires more than a room full of experts promoting their own research ideas; the most productive collaborations are based on trust and communication amongst people and their organisations. However, there are a few barriers to creating the ideal group dynamics, such as interdisciplinary silos, unclear team objectives and complexity. BNZIC wanted to explore how these barriers to collaboration could be overcome.

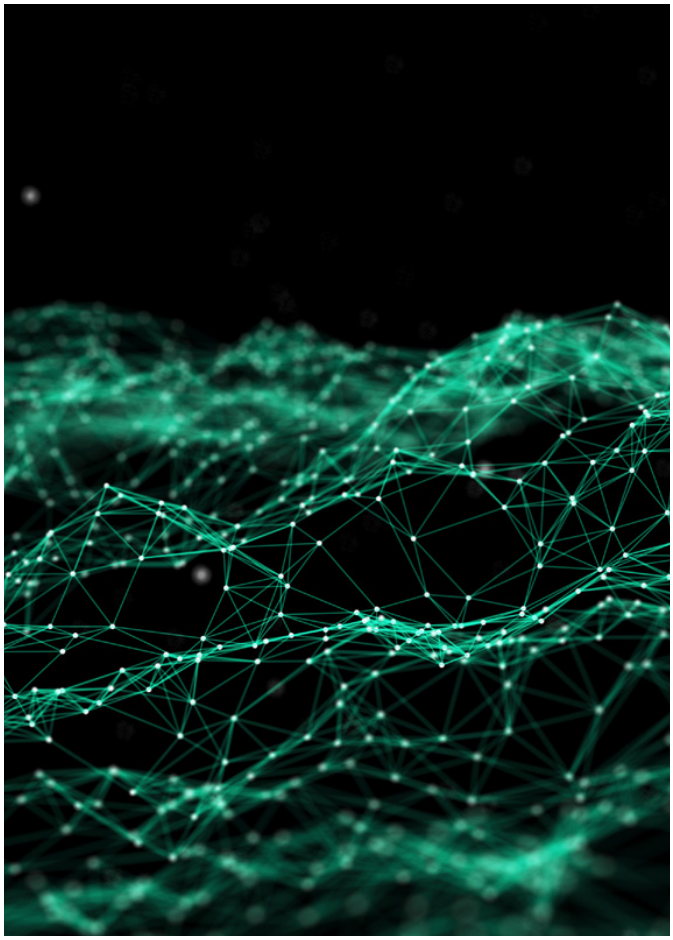
With this in mind, SfTI chose to experiment with the Concept-Knowledge (C-K) Method during Covid. This process was applied first to refining the Veracity Spearhead, which aimed to develop technologies that could not only close the veracity blind spots inherent in value chains, but that would achieve this in a way that empowered the full range of market participants.[17]

*"SfTI was looking to build the behaviour and capacity of our researchers to innovate and collaborate in new ways. The C-K approach has been used extensively internationally, so we felt it could add something new to New Zealand's innovation collaboration tool kit."*

An Australian-based facilitator ran a series of C-K online sessions. The process used three broad principles:[18]

1. **Knowledge mapping**, which involves unveiling the total knowledge base of an interdisciplinary group to identify areas of commonality.
2. **Concept exploration**, which aims to develop original ideas that offer non-conventional pathways to solving a problem.
3. **Mindful deviation**, which is about reframing; consciously stepping away from established disciplinary structures that can cause 'fixed' thinking.

Through close observation of the process, BNZIC found that the knowledge mapping process helped to form social bonds between individuals and fostered a sense of shared direction. Further, exploring key concepts facilitated open conversations that retained technical depth, while mindful deviation worked to flatten institutional hierarchies, and resulted in individuals 'unfixing' themselves from roles they held outside the project. This experiment indicated there was value in using structured design-led processes to form collaborative research projects.



16. The Building New Zealand's Innovation Capacity Spearhead is discussed in the following section.
17. For example, taking the example of a meat product, its value chain will involve livestock farmers, meat processors, logistics, retailers, restaurants, consumers, and industry regulators. The research seeks to enable all participants to contribute to, and benefit from, a transparent and trusted information source, which could enable compliance and sustainability, while also establishing provenance surety to consumers around the globe. For Aotearoa's producers, this means having a way to demonstrate veracity and quality, giving them an edge over competitors.
18. *Effective collaboration is built on strong (micro)foundations*, SfTI News Article, January 2024. https://www.sftichallenge.govt.nz/news/how-do-we-get-people-to-work-together-to-tackle-the-global-challenges-of-our-time/

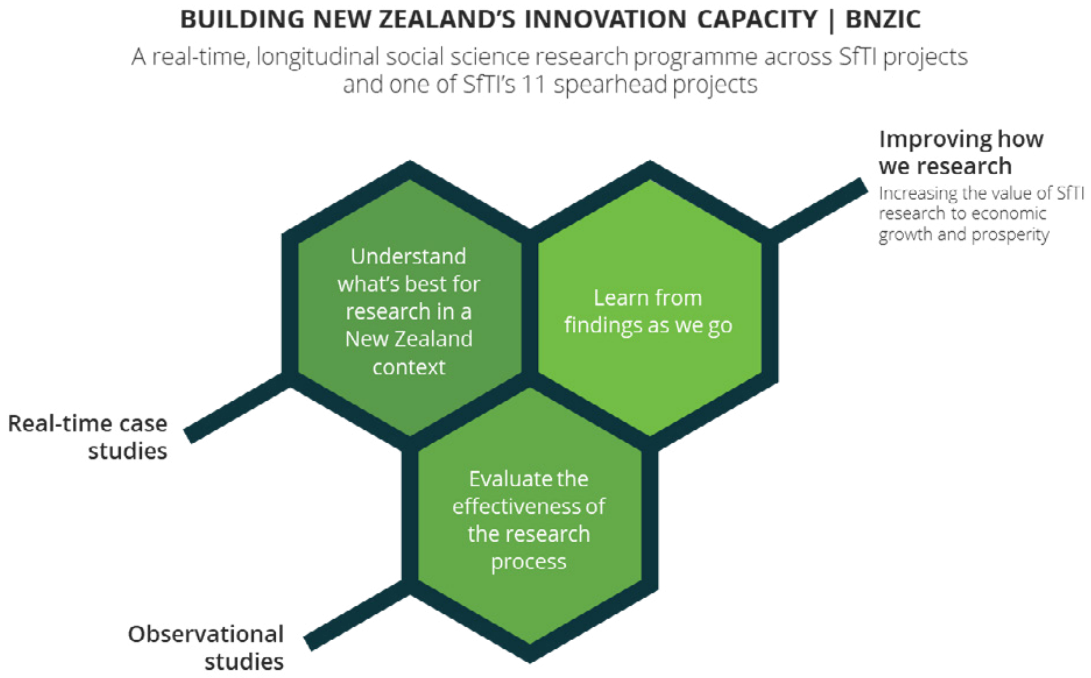
## B. BUILDING NEW ZEALAND'S INNOVATION CAPACITY (BNZIC) SPEARHEAD

Through BNZIC we have learned that our science system needs to:

1. Be designed for inclusive collaboration, supporting science-based and networked open innovation
2. Include both science-based innovation and mātauranga Māori
3. Value technical and human, relational and entrepreneurial skills

No other structure in Aotearoa New Zealand's innovation system has the specific goal to enhance capacity to apply scientific discoveries, meaning research findings can languish in labs and journals, never meeting their real world potential. Because of SfTI's novel focus, it invested in the **Building New Zealand's Innovation Capacity (BNZIC)** Spearhead, which observed other SfTI research teams to better understand how these collaborations evolved over time, and to identify what factors constituted barriers and enablers to science-based innovation in this country.

## Building New Zealand's Innovation Capacity[19]




This project was an unprecedented effort to understand how researchers, industry and Māori communities, work together to innovate – and to point the way forward for more productive collaboration that could boost this country's collective R&D efforts.

In his 2018 Science Quality Review Report, Professor David Williams described BNZIC as "*the project that most embodies the stated mission: how to enhance the capacity of New Zealand to use physical sciences and engineering for economic growth*." What made the project so interesting is that it essentially utilised SfTI as a living laboratory for observational and experimental research on science and engineering as it played out in relationships between and within academia, industry and communities.

### How did BNZIC fit into the Challenge?

People have not always understood the role of this Spearhead; there was an initial expectation that BNZIC would provide evidence of SfTI's KPI achievement, or serve as consultants of a sort, guiding Spearheads along the way (this has happened to an extent) but it hasn't necessarily worked out that way.

*"Social scientists aren't social workers. So scientists often used to bring on social scientists to help them get engaged with industry, which is not [BNZIC's] role. They're not there to be the broker and the facilitator, although they had done some of that, but that was not their role. They're genuine researchers in their own right."*

What has BNZIC produced? After almost a decade of investigation, the BNZIC team has produced a rich body of knowledge (including more than 30 published papers, four influential reports, industry insights and policy briefings, and a book 'He Pou Hiringa, Grounding Science and Technology in Te Ao Māori' ) that contribute to the understanding of new ways to practice innovation.

In their Science-based Open Innovation report,[20] BNZIC identified some of the basic drivers of impactful research, such as early engagement with research partners, prioritising research team formation, incorporating intermediaries into the innovation process, and getting out of the lab to better connect with real world priorities. And as already mentioned in the current document, supporting collaboration is key to Mission-led research, as are considerations of IP and contracting, particularly when working with Māori.

19. Source: BNZIC Presentation to the Science Society Int Ottawa, 26 Jan 2024.
20. Science for Technological Innovation. (2022). *He hiringa hangarau, he oranga tangata Building New Zealand's Capacity for Science-based Open Innovation*

A particularly influential piece of work generated through BNZIC was Jarrod Haar and Willy-John Martin's article on **Aronga Takirua**:

*"It's something in all honesty that I think has been in existence for a long time and has been discussed by Māori for a long time. But with my co-author, Willy-John Martin, to actually capture the story and publish a good academic article on it, that's really leveraged the kind of attention to the role that Māori scientists do. So they're doing both the scientific journey and the kind of translation into Māori communities of their research, or their team's research. And of course, the disadvantage there is that they're then doing two jobs for the price of one and are more likely to burn out, which is a disadvantage. So, I think just bringing attention to an ongoing issue, and then kind of challenging the sector to do a better job in looking after Māori workers and Māori professionals in the research, science and innovation sector."*

How can projects counter the double shift experienced by Māori researchers? Useful strategies include properly resourcing Māori relationship-builders and supporting Māori capacity development. With regard to Māori partners, considerations of absorptive capacity should be top of mind, for example, through incorporating upskilling opportunities for hapori Māori within the research and enhancing Māori control over Māori data.

Having closely observed research projects over a number of years, BNZIC were well-placed to offer advice on structures and practices that support Mission-oriented science - this is particularly relevant at the current time with Aotearoa New Zealand's RSI system under review.

### BNZIC's recommendations for science policy:[21]

#### 1. Stretchy and sticky science inspired by collaboration

Stretchy research involves looking five to ten years into the future to develop novel ideas. Sticky research is science that makes sense for Aotearoa New Zealand. To generate stretchy and sticky research, science ideas need to be generated in collaboration with industry, Treaty partners, stakeholders, and scientists. A collaborative and diverse approach must be adequately resourced as part of the science system.

#### 2. Carefully considered research leadership

Careful consideration is essential for the leadership of research priorities or challenges. A partnership approach embracing mātauranga Māori and diverse knowledge sets is essential. The leadership team should encompass a variety of knowledges, disciplines, and relevant impact for each challenge.

#### 3. Opportunities for risk-taking and failure

Embracing a culture that allows for failure is crucial in the science system. Fostering innovation necessitates taking risks in both research organisation and its execution. To encourage science-as-UNusual, teams should feel empowered to be different and explore diverse approaches for innovation.

#### 4. Prioritise relationships and capacity development

People are at the heart of any mission-led science programme. Relationships need to be nurtured, given attention, valued, and funded. Team members should be carefully chosen, not just for their technical skills but also because they are the best 'fit' for that science team. In addition, capacity training and mentoring should be offered to all team members for the leadership, relational, and impactful skills that are not always inherent in researchers.

## C. SCIENCE QUALITY

While SfTI focused much attention on innovating the practices that wrap around research, it was also required to produce technical research of a high standard. To this end, the Challenge has undergone two Science Quality Reviews (SQRs), as required by SfTIs KPIs because it had (intentionally) not formed an International Science Advisory Board as many other Challenges did.

The first review was undertaken by an international panel chaired by Colin Knox in late 2017, prior to the Midway Review. The panel's findings were overwhelmingly positive and commended the Challenge's approach to creating a research programme which incorporated Vision Mātauranga, ensuring that one of New Zealand's unique characteristics was capitalised on. Further, the focus on collaboration and capacity building was noticeably paying dividends and could usefully be extended further. Panel members were impressed that most individual projects were both 'stretching' science and had an eye towards commercialisation.

The second, a Science Quality and Impact Review led by David Williams, was undertaken in late 2021. This review also considered the potential Ending with Impact Projects (EWIPs), and provided useful general feedback for SfTI's leadership to consider:

*"It was a really good process for us in terms of actually really getting a feel for where a lot of the research sat from a 'stretch' point of view."*

21. https://www.wgtn.ac.nz/bnzic/stakeholder-insights/policy-advice/deliberately-different-science-programmes

# 5. Managing the Challenge

**"SfTI had the triangle of time, money and resources, a servant leadership, and also a clear mission. That combination ensures you have the things needed in order to achieve a very clear goal. It's like you can't actually top that, it's very rare."**

The Challenge's Board, Kāhui Māori, Directorate, Theme Leaders and Programme Office, have all worked together to enable Mission achievement. Each individual has brought their own unique set of skills and knowledge to the task, and carefully nurtured team dynamics have brought out the best in everyone.

The current section looks at the contributions of each group in terms of how they interacted with each other and contributed to SfTI's overall success. It also touches on some of the problem-solving work undertaken by these Challenge stewards.

Gifted by renowned Māori orator, tikanga and te reo Māori expert and academic, Tā (Sir) Pou Temara (Ngāi Tūhoe, KNZM), this whakatauākī represented the intent of the Challenge: to connect technology and people in ways that are beneficial and reflect te ao Māori:

He hiringa hangarau,
he oranga tangata;

Innovation in technology
for the benefit of people.

## A. SFTI TEAMS

A number of people stand out as being particularly enabling of the SfTI Mission - they were the right people, at the right time, working on the right kaupapa. They have taken their places throughout the organisation within governance, management and advisory roles, working in the Programme Office and as researchers:

*"Whole organisations move on a few key individuals - whole movements, whole projects. And it's not to say that the others are not important, but there's something very catalytic about those individuals at that particular time. And I don't think it's something that you can design for - you just have to discover them and kind of hope for the best because talent is a very rare commodity."*

### Governance Board[22]

John Bongard, the first and longstanding Board Chair, was universally well-regarded across the Challenge, and very supportive of things Māori. His leadership style ensured that while the Board fulfilled its compliance requirements, it did not become bogged down in process and administration.

John recruited Linda Cooper (later co-Chair) for her business skills, which were a much-needed complement to the existing science, academic and government expertise already resident:

*"We had economic KPIs, so I really liked that component. I was driven to have outcomes and that there was some development stuff, not just research."*

The SfTI Board's quarterly meetings worked quite differently to other Boards in that they might be attended by 20 people or more, even though there were only four or five Board members at any one time. SfTI's Board was made up of people with non-scientific backgrounds, so the approach was to involve many others in the meetings, including Science Advisors, a Callaghan observer, an MBIE observer, and members of the Programme Office. Those who had open minds, and/or who could explain why certain things were important were crucial to the overall mix, whether the topic of discussion was technical and scientific, related to Māori culture, or interrogating government policy and systems.

Several of those interviewed for this legacy report say the Board meetings were a novel experience:

*"I came in and there was this huge group - I remember I counted - there were 21 people around the table. I remember saying to John, 'This is a really big table!' But John still chaired it, and I have to say it's been one of the most effective tables I've sat around."*

22. Board: Linda Cooper (co-Chair), Te Taka Keegan (co-Chair), Gottfried Pausch and Kat Lintott. Science Advisors: Richard Blaikie, Margaret Hyland, John Raine and David Williams. Rangatahi Board Advisor: Daniel Xu.

*"The Board members are outnumbered three to one at Board meetings, but then it allows them to be just trustee Board members. They didn't have to be technically savvy because whenever proposals are brought along, the Science Advisors get an opportunity to speak about the science value."*

It was during a time of change within the Governance Board that the option for co-Governance came to the fore. When John Bongard and Craig Ellison left the Board in 2021, Traci Houpapa joined. Traci was Chair of the Federation of Māori Authorities (FOMA), a very influential entity that has a significant stake in the New Zealand economy, and this contributed to her bringing a particular dimension to the Board. She set SfTI the challenge of moving to co-Governance, and with the Programme Office Manager working behind the scenes, the change was made in March 2022: Te Taka Keegan became co-Chair alongside Linda Cooper. Each brought deep and complementary skill and knowledge bases to their roles.

While this development was not a necessary solution to an obvious problem, it did send a clear signal to all those working inside and outside of SfTI that partnership with Māori was integral to the Challenge.

Two Governance Reviews were carried out as a requirement of the Challenge's KPIs. The first review was conducted by departing Board member, Craig Ellison, while BoardWorks undertook the second.

Both reviews were favourable towards how the group was performing, although risk management was highlighted as an area for improvement. The Board was prompted to highlight identified risks in its MBIE reporting, and this was an easy recommendation to follow given the risk-related expertise possessed by members, including Linda Cooper who had international commercial experience to draw from.

The SfTI situation was somewhat different compared to other Boards because it did not have the usual responsibilities such as Health and Safety. But nevertheless, risk management certainly could have been an issue for the Challenge given the experimentation SfTI undertook around developing new processes. Careful stewardship by senior personnel ensured these activities have kept SfTI within the bounds of what can be justified.

## The Kāhui Māori[23]

The Kāhui Māori was an advisory group made up of Māori thought leaders who guided SfTI from its earliest days. It brought a Māori lens into strategy development, planning and activities, influencing the Capacity Development Programme to ensure it strengthened cultural capability of leaders and researchers alike. The rōpū were the primary architects for how SfTI could utilise the Vision Mātauranga (VM) Policy as an enabler for infusing mātauranga Māori throughout its work.

Inviting the non-Māori Director onto the Kāhui was a strategic move, and also a somewhat controversial one (initially) because it had the potential to dilute what would otherwise have been an unambiguously Māori space. However, early fears were allayed by the way the Directors, first Margaret Hyland and then Sally Davenport, approached this role. As a member of the Kāhui noted:

*"[Sally] has been a connector between the discussions at the Kāhui table and the Board and Director's table as well. And I think that was a real strategic stroke of genius from Reece [Moors]. Sally was really good at balancing and evening out intention versus impact, and ensuring that our researchers or our partners were thought about in the same conversations."*

One of the main roles for the Kāhui was supporting Māori researchers so that they were free to bring Te Ao Māori into their work, and this was achieved through providing mentoring and advice, and making connections as needed. Additionally, they identified opportunities to connect with Māori stakeholders in ways that have enhanced collaboration, which in turn increased research participation by, and benefits for, Māori.

The question of whether or not to merge the Kāhui Māori and Governance Board was one that all National Science Challenges explored at one point or another during their ten years of operation, with eight of the 11 Challenges choosing to do so. SfTI's decision to maintain a separate Kāhui rōpū was somewhat unusual, but nevertheless, well-considered.

It was a very conscious decision based in large part on the strong Māori representation already existing across the organisation, including on the Board, the Leadership Team and the Programme Office, and because the Kāhui Kaihautū and other members held a very specific view of the Kāhui's role as applying a Māori lens to advise on research projects:

*"It's like a technical advisory group, not necessarily a governance advisory group, and we had enough Māori people on the Board to do the Māori governance."*

*"The Kāhui's perspective was, 'How do we help Māori research? How do we help Māori researchers? And, let's figure it out.' And the Board is where we request funding and things to support us. I think as a Board, that's how you want to be able to empower people to go and do their own things."*

## Senior Management[24]

Margaret Hyland was the inaugural Challenge Director (2013-2016). She saw the opportunity presented by the NSCs and wanted to be involved in shaping the SfTI Challenge: "*I could see the potential and benefit of having a collaborative focus, and I was ambitious for it from the beginning*." Her subsequent role was with MBIE as their Chief Scientist, and by that time, the Challenge was set up and well on its way, with the right people in key roles:

*"There were enough others there who really got the kaupapa."*

When Margaret decided to move on, she asked members of the Leadership Team for recommendations on who should replace her. Stephen MacDonell's advice was that while anyone on the leadership team could manage it, Sally Davenport had a unique set of skills that marked her as an excellent option *"because of her policy focus, her understanding of innovation and her connection to Wellington."* Sally's skills and experience had indeed been highly relevant to the BNZIC Spearhead (where she began her work with SfTI), as well as overseeing the entire Challenge with its focus on collaboration and capacity development. But she also had a technical background, with a PhD in Nuclear Magnetic Resonance, and had worked with the MacDiarmid Institute and Te Punaha Matatini.

23. Nancy Garrity (Kaihautū), Katharina Ruckstuhl, Vanessa Ngaroimata Clark, Pauline Harris and Sally Davenport. Rangatahi Observers: Te Rina Kowhai and Te Mauri Kingi.
24. Sally Davenport (Director), Bruce MacDonald, Stephen MacDonell, Don Cleland, Katharina Ruckstuhl, Pauline Harris, Urs Daellenbach, Elspeth MacRae and Geoff Chase.

Sally was appointed to the Director role in 2017, and as the organisation was on a steady growth trajectory, it was decided a Deputy Director was also needed, a role taken up by Bruce MacDonald at around the same time.

A number of other Challenges established co-Directorships as a way of ensuring a genuine leadership approach between Māori and non-Māori, however, a notable consequence of SfTI's baked-in cultural capability building, and of the (non-Māori) Director being included within the Kāhui Māori, was that a Māori co-Directorship was considered unnecessary:

*"What people don't see from the outside is that in terms of what SfTI has delivered around Vision Mātauranga - the funding that went to VM projects, and the Māori researchers that have been supported, among other things - those outcomes have been delivered without needing those mechanisms because the environment has not been a hostile one."*

*"We don't need co-Directors because our Director is coming to all of our [Kāhui] meetings and is right on the pulse with us."*

Mentorship has been an important contribution offered by members of the Leadership Team - that in itself is unusual across the RSI system and effectively constituted an experiment, and one that those involved had to feel their way into:

"*I remember having one of my first discussions as a Theme Leader with Don [Cleland] and Bruce [MacDonald], and they said, 'Right, one of the things we're going to do is ring up the researchers and visit them and spend some time with them.' I thought, 'Woah, what have I got myself in for here? I didn't sign up for this!' But it was actually a great thing. I remember doing the first one with Peng Cao, thinking, 'I've got no knowledge about batteries, what am I going to talk to him about?' But it was a really good discussion and from there on, it was a really enjoyable part of the job. We were there really to say, 'How's it going? What's getting in the way? What do you need? Are you going for capacity development? Have you thought about this or that?' And it was a great chance to get to know people and the work they were doing, because of course they're passionate, they want to talk about it. You just don't get that in any other part of the system - we had the license to do that, to add a tweak. This was a SfTI thing.*"

Mentoring from the Leadership Team empowered the SfTI community in their research, and the hope was that having enjoyed that type of support once, those individuals would look for new mentors in their subsequent roles, and feel comfortable in doing so. "*It's creating those patterns of behavior where SfTI was the incubator of how to do it*."

## The Programme Office[25]

One of Sally Davenport's first decisions as the new Director was to engage the right person as Programme Office Manager. She had already identified Reece Moors as the ideal candidate because of his strategic thinking, government experience, and good people skills. He was also well placed to drive the VM agenda and manage external relationships with MBIE and community-based Māori partners. Further, he also contributed to the cultural capacity of his non-Māori colleagues both formally and informally.

*"Having our Programme Office leader taking a very Māori approach saw the rest of the Leadership Team always having to pick up and run with or improve our own [cultural development]. It helped really embed that in our DNA."*

This recruitment decision proved to be an excellent one as despite Reece leaving before the Challenge's end date, he helped to establish an extremely enabling team culture that resulted in consistent, deep support for the Mission.

Because of SfTI's constant focus on developing new practices and processes in the name of Mission achievement, the Programme Office operated in a unique environment where individuals could take ownership of their roles and feel that they were making a significant contribution, which Sally has described as "*entrepreneurial*."

"*The Leadership Team will make a decision and the Programme Office goes and makes it happen, which is fantastic. I wish I'd had that all through my career. But it also has meant that sometimes they've been working in really ambiguous times, so they've had to go and figure out how things were, come back and work with people like Stephen [MacDonell], Bruce [MacDonald] and Don [Cleland] on the details. So, it's been really permissive for them.*"

25. Raewyn Tse, Denise Cutler, Georgie Wiles, Randall Gravit, Deborah Crowe, Latisha Ablett and Fiona Pattinson.

*"We just do stuff. We get shit done. There's never any pushback or anything. It's just: if this needs to be done to advance whatever we're doing, just get it done."*

Reece's management style enabled this level of autonomy, first in recruiting highly skilled and confident team members, and then letting them shine in their roles:

*He understood, gave me autonomy when it came to managing the CD Programme. I just knew that he trusted me a hundred percent."*

Interestingly, the funding parameters set by MBIE meant that a very hierarchical administration, where layers of management could oversee all the small details of staff activity was not on the cards. Just 5% of the total budget was available for administration. At one of the Science Quality Reviews, a member of the Programme Office spoke with a counterpart who ran large billion-dollar science programs in the EU – they were astounded at the small proportion of total resourcing made available for administration and noted that, "*Unless the Programme Administration gets at least 30% of the total funding, we are just not interested*." The demure percentage of SfTI's budget allocated to administration left a significant amount available for distribution according to the scientists' needs:

*"From a government perspective, it was a brave call to say, we are going to take this funding and hand it over to the end-user to manage. This is going to have a very light touch in terms of government bureaucracy, and basically MBIE will hand the crown funding to the academics and allow them to determine where to put it to best use. Ultimately, SfTI has proven the wisdom of that decision and we've been able to make good on it."*

The Programme Office team have managed funding so that a greater proportion was available early in Tranche Two rather than having funds spent evenly across each remaining year. This has allowed some flexibility when the Leadership Team have wanted to implement new ideas, such as the Ending with Impact Projects or to urgently address emerging issues: "*We've been able to say, 'Yes, we've got the money here and we can do it'. And we could action that fairly quickly without saying, 'You're going to have to wait until the next financial year before we get our next drawdown of funding'. So that's actually worked out very well*."

As the Challenge's attention turned more strongly to impact-making in the second tranche, a commercialisation expert was employed to help facilitate this, with the role sitting within the Programme Office. This seemed quite a change in focus for some in the SfTI team, but the value of this addition soon became clear:

*"We really ramped up then, and it turned out that there was a gap and that we actually needed someone to help broker the connections to other parts in the sector that would help the teams. And we were skilling them up to be able to do innovation, and then we could actually connect them to the next stage, into other money that would accelerate that as well. And that was so critical."*

The new recruit quickly went about reviewing SfTI's research projects relative to their commercialisation promise. He set up a system for identifying impact potential, which provided a very useful level of understanding across the wider portfolio:

*"He had the experience and he could see where there were gaps. He could see where people were targeting the wrong market. He knew where to get help. He had a budget so he could get support for market or IP, or investigating freedom to operate. And that was all capacity development for the teams as well along the way."*

The next Commercialisation Development Manager brought a good knowledge of the start-up ecosystem. She exposed researchers to some important events such as Angel Runway and the Electrify Conference, and to other resources like tech-oriented co-working spaces. This exposure opened the researchers' eyes to a new world.

Researchers and management have now experienced the benefits of an enabling administration, and while it has been much appreciated, there is some suggestion that even more could have been provided in terms of support managing relationships and assisting with strategic reflection.

## B. PROBLEM-SOLVING

It was noted during interviews for this Legacy report that there can be an element of "*butt-covering*" in government situations, but SfTI had different drivers and responsibilities, and so had a degree of freedom to meet problems creatively:

*"Rather than spending a lot of energy and time and kind of explaining why, if a gap is identified, we try and find a solution to fill that gap."*

### 2020 VM Seed Funding

This creative problem-solving approach came into play after the 2020 VM Seed Funding decisions were announced - there was swift and vocal public criticism from some Māori academics because it appeared (erroneously) a preponderance of non-Māori researchers had received funding for VM-led research. The Kāhui Māori and Leadership Team swung into action to formulate a coherent response:

*"There was such a genuine effort to not only recognise what was said and respond in the appropriate way, but then from leadership to then ask, 'How do we do it better next time?' And genuinely, it was learning. It doesn't sound like rocket science, but it's a rare culture to have in the government space. And then as well to then have the flexibility and the resource to address the problem and make a change."*

Ultimately, the constructive exploration of the issue by the Challenge's wider leadership saw a genuine re-evaluation of SfTI's own processes to ensure any mistakes were avoided or quickly rectified and that this type of criticism would not arise again:

*"We're all about experimentation, innovation and pivot. You can't progress without pivoting, changing and doing it different, that's a scientific way. So then it's almost like that approach seeps into the administrative side of things."*

### Intellectual Property Management

During Tranche One, a Māori partner raised concerns about Intellectual Property protection for their information and stories, but the existing IP clauses in SfTI's standard partner contract did not allow for this. In a team effort involving the Kāhui Māori, Programme Office and one of the Theme Leaders, and two external Māori lawyers, Lynell Tuffery Huria and Tai Ahu, the relevant clauses were rewritten.

*"We kept telling ourselves we might not get it right, but it's better than what we've got. It's a first step. We're going to try this and let's see what happens. And then we just treated it as a learning experience."*

In addition, an IP Policies and Principles document was created to provide extra guidance on what was expected. Throughout Tranche Two, anyone that received SfTI funding had to sign up to the adjusted contract, including universities. The IP Management Plan went out to partners and there was some minor feedback, but overall it was well-received.

*"It's a best practice example of how you contract research while still respecting and maintaining the integrity of Māori where that rightly belongs."*

### Excerpt from SfTI's Intellectual Property Policies and Principles document

When the Project involves any Mātauranga Māori or Taonga Species, the Parties (or the Managing Party) will:

1. require employees, contractors, grant holders and any other personnel to acknowledge the relevant ownership and rights associated with Mātauranga Māori Project IP;
2. unless agreed otherwise, keep the Mātauranga Māori, Taonga Species and the Mātauranga Māori Project IP out of the public domain;
3. consider whether protection options other than the statutory Intellectual Property options would better protect the Mātauranga Māori Project IP;
4. consider what steps can be taken to stop misuse and misappropriation of Mātauranga Māori, Taonga Species and the Mātauranga Māori Project IP; and
5. work with Māori to enable Māori to exploit or commercialise any Mātauranga Māori, Taonga
6. Species or Mātauranga Māori Project IP.

"To me it was quite easy because the extra provisions in the IP contract weren't onerous, and they made sense. If you were supportive of there being Māori background IP and things like Māori taonga, things of value to Māori, which might have a different value for other people, but for them they had value. So if you accepted that, then it was pretty straightforward. I thought you either agree with that or you didn't."

# 6. Measuring Impact

"I think that SfTI did some really innovative stuff such as the VM ballot system for the Seeds. And the fact that we've done it, people are less frightened to do that next time. Some of the high tech stuff that's happened both through the Seed projects and the Spearheads is internationally leading edge. The fact that so many researchers have been exposed to that Māori world in a very user-friendly way and are relatively comfortable now, more comfortable than they may have been in the past - that'll endure regardless of where they end up."

## A. HOW CAN WE DETERMINE SFTI'S IMPACT?

"One way or another we achieved most of our targets, which was pleasing."

Challenge impact is a difficult thing to measure for several reasons. First, the Mission given to SfTI was extremely wide in scope: *to enhance the capacity of Aotearoa-New Zealand to use physical sciences and engineering for economic growth and prosperity*. Second, the timeframes between applying new systems and processes as well as carrying out research, and then subsequently observing impacts can be expected to be long. Third, with multiple initiatives, investments, actors, insights and needs coming into play over time, it is difficult to attribute cause to any future benefits observed.

We will likely never know definitively what return on investment this or any other Challenge has produced, however, we can still understand some of SfTI's likely impact.

**Q:** "Has the Challenge solved any of these big problems?"

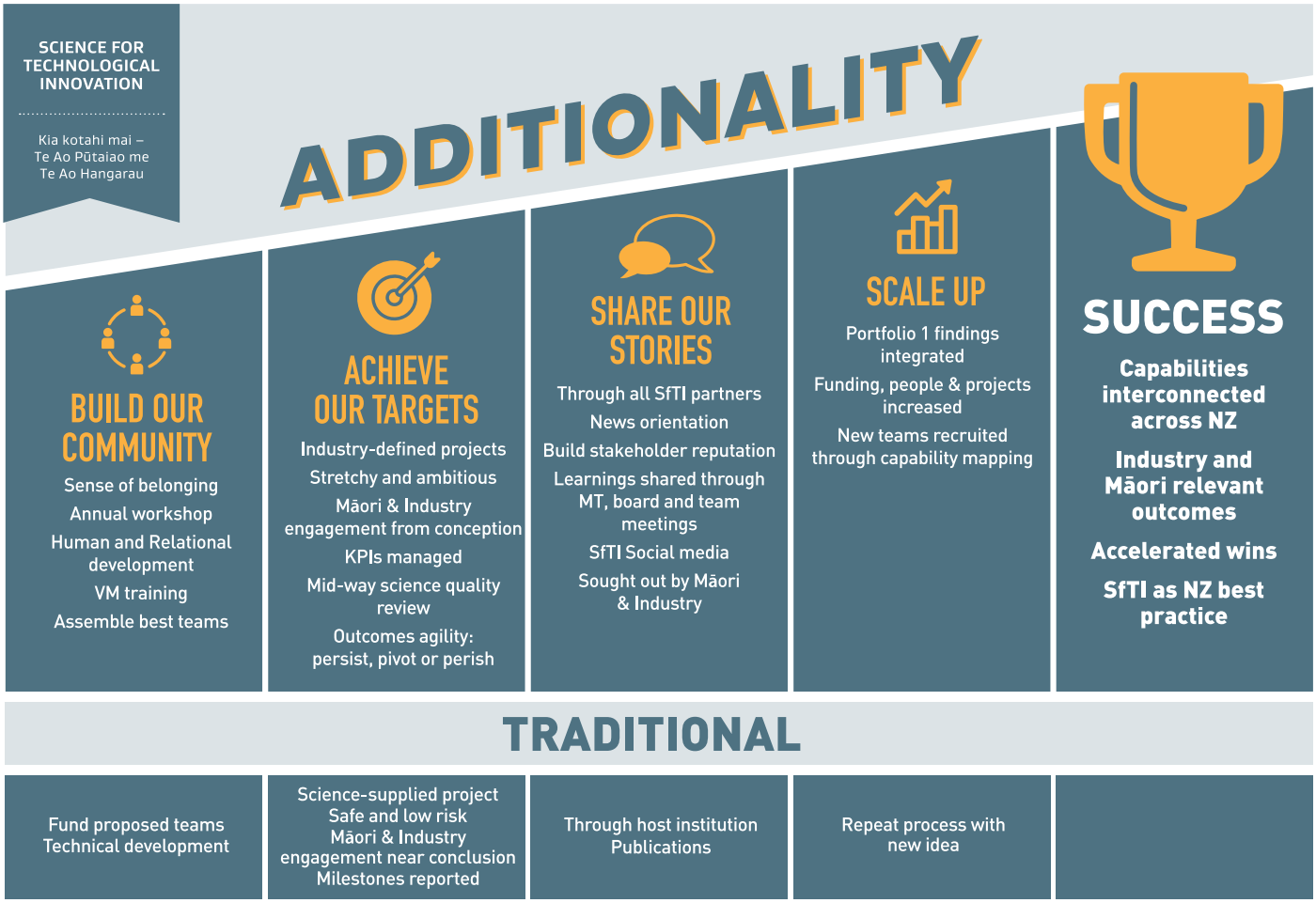
**A:** Well, solving is a long-term thing, right? Solving is slow. I think you don't get stuff in a hurry in any physical science and engineering."

## B. ADDITIONALITY

The NSCs were originally established under the assumption that additional research, progress and impact could be generated by collaborative research. In the case of SfTI, its budget of $106m over ten years was bound to result in some level of impact, but the only way to really understand the value of the NSC investment would be to compare Challenge impacts with impacts from research funded via other mechanisms such as the Endeavour or Marsden funds. This is the question of additionality.

*"How have these different methodologies fared when we look at them with respect to one another? And let's see if we can adjust the mix a little bit."*

## SfTI's Framework for Creating Additional Benefits for Aotearoa New Zealand through its Activities




SfTI was very purposeful in thinking about additionality, baking it into its strategic planning from very early on. There are clear signals that SfTI did indeed contribute considerable benefit to Aotearoa New Zealand as a result of its activities. As an addition to the benefits already presented throughout this document, the sections below explore examples of SfTI's impact with reference to each of three types additionality typically related to research investment: Input, Output and Behavioural.[26]

26. Davenport, S. (2017, 13 July). "Additionality": How will we know the National Science Challenges are making a difference? In *Sciblogs*.

## A. INPUT ADDITIONALITY

This refers to an increase in research investment made as a result of public funding that may not have happened otherwise.

### SfTI has affected this type of impact, for example, through co-funded projects.

For example, the *Biosecurity Technology Spearhead (Detecting the last predator)* received $1.2 million in co-funding from Predator Free 2050, and a further $300,000 from the BioHeritage National Science Challenge. These partnerships have enabled the original research project to be extended and to access additional expertise.

*Te Pā Tūwatawata (Māori controlled data repositories)* is another example, where the project followed on from the two Māori Data Futures Hui originally co-hosted by SfTI. The Challenge went on to contribute partial funding to a larger work programme led by Te Kāhui Raraunga Charitable Trust, which works closely with the Data Iwi Leaders Group.

### The relationship with FOMA enlarged both organisations' activities.

The Challenge wanted to establish relationships with larger Māori organisations as a way of contributing to capacity development of the wider innovation system, and so capitalised on existing connections within its community. As a "*trusted broker for all parties*," Programme Office Manager Reece Moors was able to make an introduction with FOMA's Chair, and it was agreed that SfTI would contribute a small amount of funding for an Innovation Manager role. FOMA Innovation subsequently was established as an arm within the wider organisation, with the purpose of stimulating innovation across the FOMA network, and a particular interest in science. Theme Leader Stephen MacDonell offered his time in a technical advisory capacity.

*"FOMA were an organisation that was interested in getting into the innovation space, and they appointed a Chief Advisor Innovation & Research."*

At the recent FOMA Summit, Te Horipo Karaitiana (Chief Advisor Innovation and Research | Pou Whakatāmore Hangarau at FOMA Innovation) talked about what the FOMA network should be looking towards in terms of the tech and innovation space. As one senior member of the SfTI team observed, SfTI has helped them to formulate this direction.

Additionally, SfTI partnered with FOMA Innovation on two delegations to Australia in connection with CSIRO. Initial plans for a Pacific Indigenous Innovation Summit were formed, but this has not eventuated.

*"We're breaking down those barriers, which is great because I think the trouble with science is it can be so complex and niche - it builds these little silos and doesn't bring other people in. And I think one thing SfTI has worked super hard on, and I've gotta tip my hat to the leadership, is how hard they've worked to bring those stakeholders in. That's one thing we can take away from SfTI is that Māori engagement's really positive, right? Māori want to be engaged with sciences."*

### The Rauika Māngai was formed through the Challenges.

Taking our view slightly wider, SfTI made a significant contribution to establishing the Rauika Māngai, providing the secretariat and supporting the time of previous Capacity Development and VM Manager, Willy-John Martin. One senior member of the SfTI team recalls an early meeting attended by Kāhui Māori from across the Challenges and MBIE where a lot of Māori researchers were angry because they felt that MBIE wasn't enabling Māori to do Māori research within the Challenges:

*"Out of frustration, I think, they decided to set up the Rauika Māngai, and it was an opportunity for Māori in National Science Challenges who weren't getting a fair deal to work collectively to address those things."*

There was not the same sense that Māori researchers within SfTI were coming up against these same problems, but nevertheless, support was willingly offered for this new rōpū.

## B. OUTPUT ADDITIONALITY

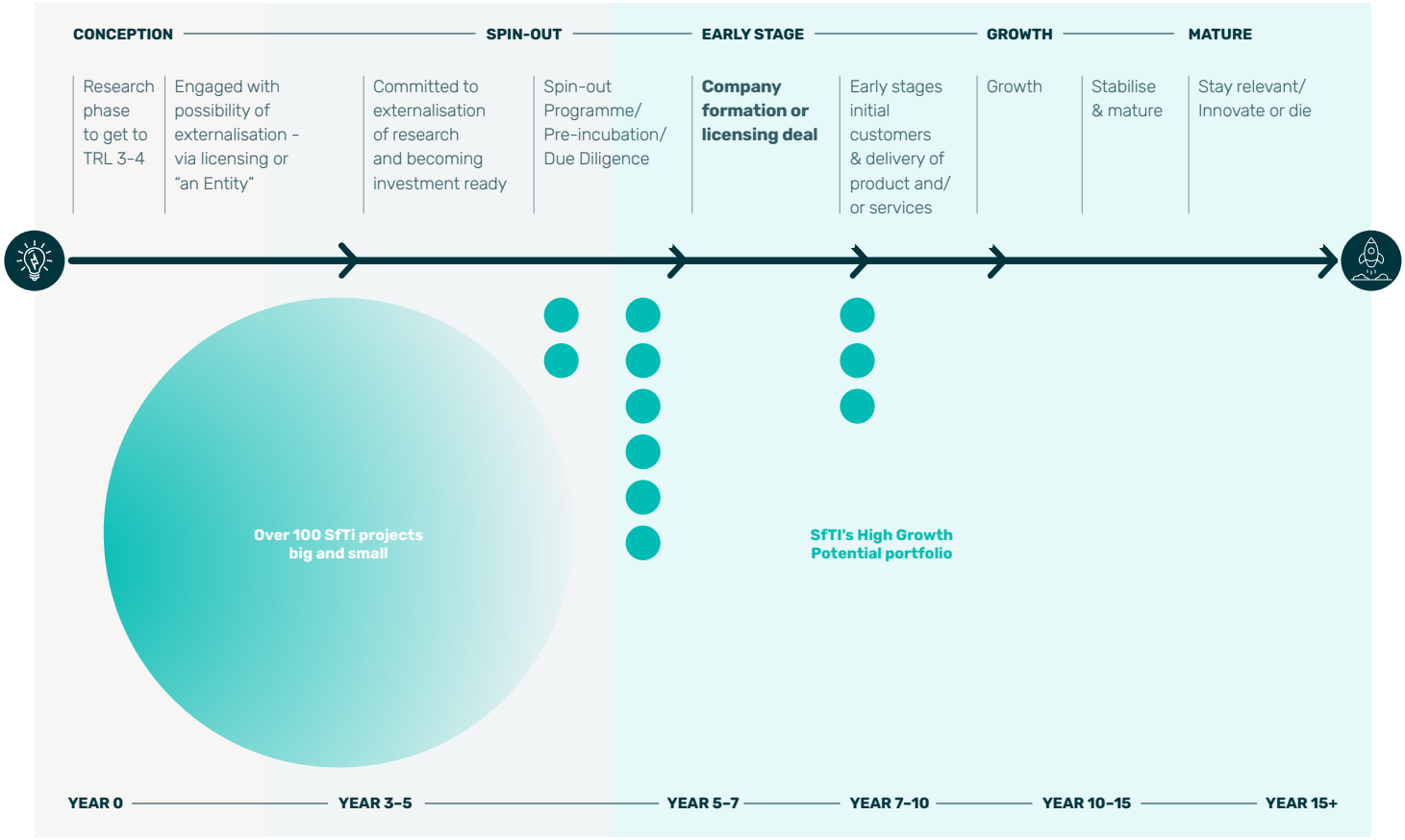
This type of additionality covers direct outputs such as papers, patents and specific technologies, but also longer-term benefits targeted towards specific groups, or new startups. Such impacts can take some time to materialise, however, SfTI has clearly set a pathway in this direction, particularly with regards to commercialisation of research.

### SfTI's research projects are expected to make a significant economic contribution

An independent review carried out by the NZ Institute of Economic Research (NZIER) in 2024 analysed a portfolio of 11 of SfTI's projects. Findings indicate that at least $300 million per annum will be added to the economy within 10 years as a direct flow-on from research started during the life of the Challenge. As already noted above, SfTI's commercially-focused capacity development has enabled researchers to pursue such outcomes.

SCIENCE FOR TECHNOLOGICAL INNOVATION

## Commercialisation journey of projects




The eleven Spearhead research projects have resulted in many positive outputs, and these are summarised in the Appendices'. The diagram above shows the progression of SfTI research across a continuum from conception to maturity. Since success is not guaranteed at any stage, fledgling firms are offered learning opportunities through the CD Programme to support them in taking their projects and careers to the next level.[27]

At a finer level of detail, a number of research projects were well on their commercialisation journeys as SfTI came to a close. These included Toku Eyes Ltd (Diagnostic), Digital Sensing Ltd (Nitrate Sensor), and TasmanIon (Aluminium-ion batteries), while the protein Nanosatellites developed by Sarah Kessans are already being launched into space. Many more research projects funded through SfTI are in the process of forming companies and engaging in capital raises.

27. NZIER. (2024). *Assessing the commercial and social value of the SfTI Challenge.* A report for the Science for Technological Innovation Challenge.

CASE STUDY

## Toku Eyes[28]

**Toku Eyes connects optometry with the prevention of a range of health issues. During an eye examination a practitioner can find indications of other diseases, such as cardiovascular, renal, and liver disease, using AI technology.**

The size of the problem Toku Eyes are addressing includes:

- $1,000 billion is the annual cost of heart disease in the United States
- $300 billion savings from reductions in CVD events by implementing lifestyle changes.

Capital-raising activities to date have been successful, with over $13 million raised in 2023, with a total of $16 million

| Economic characteristics | Potential | Comment |
|---|---|---|
| **Potential entity size** | Tens of millions | The size of the population is large - over 100 million eye tests done in each year in the USA |
| **Market growth** | 4 percent per annum (USA market) | Growing on the back of services such as those offered by Toku Eyes |
| **Potential market spillovers** | Very large, predicting the precursors of rapidly growing diseases has the potential to shave billions of industrial nations health bills | To be able to demonstrate the precursors to lifestyle diseases will have a major impact on health systems around the world |
| **Companies like this[1]** | Orion Health | Changing the focus of healthcare by improving the efficiency and effectiveness of service delivery |

### The Māori Data Futures Hui contributed to the wider conversation.

The two hui were influential in progressing the kōrero around Māori Data Sovereignty and Indigenous Intellectual Property protection:

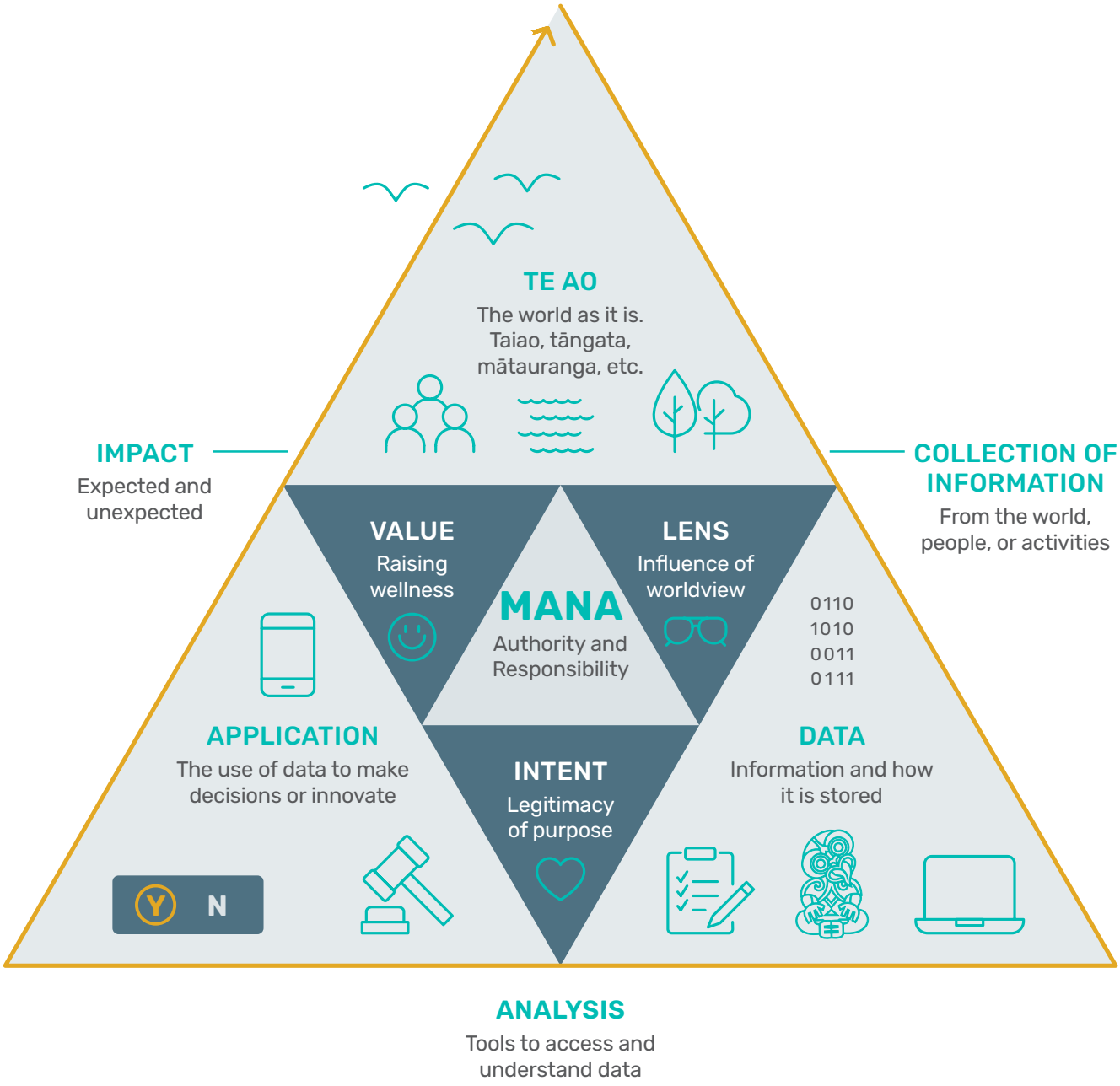
*"Those to me were really important events which highlighted a capability and a demand in our community. We didn't start it, but we were part of it and we facilitated part of it."*

The two hui made important contributions to the national kōrero on Māori Data Sovereignty, and produced resources and research that contribute to data practices that enable Māori to achieve beneficial outcomes and opportunities while maintaining the mana of their data.

Discussions during the first Māori Data Futures Hui assisted Willy-John Martin to conceptualise the Māori Data Triangle as a useful tool for thinking about how Māori data sovereignty can be supported in practice. Mana sits at the centre of this triangle.

28. *Ibid.* (p19)

## The Māori Data Triangle[29]




29. Rauika Māngai. (2018). *Māori Data Futures Hui Report.* https://www.sftichallenge.govt.nz/assets/Uploads/Download-PDFs/Maori_Data_Futures_Report-2018.pdf

## C. BEHAVIOURAL ADDITIONALITY

This is particularly relevant to SfTI's Mission and refers to both individual and organisational learning and process improvements that result from participating in a new initiative.

*"It has been very exciting to see people going through these courses, to see people getting leadership skills, to see people getting confidence in themselves, because ultimately our legacy is these people."*

As already described in this document, there are many impacts in this class resulting from myriad supports put in place by the Challenge, for example, the **Capacity Development** Programme, which was supercharged through partnerships with external organisations such as KiwiNet and FOMA. SfTI's Final Capacity Development Report recorded a range of benefits to attendees, particularly as a result of attending VM-focused education, science leadership training, and the many offerings that helped researchers prepare for a commercialisation journey. It is anticipated that those researchers will carry their new skills forward with them in their careers.

*"Just giving people money, although that's great, will not do a researcher's idea a full service. SfTI is not like any other funder, they are offering a more rounded support. Researchers just want to be researchers, and it makes a real difference when funders like SfTI help by saying; 'we can see where your vision is going, and we want to help you get there."*

The **mentoring** provided to researchers by the Kāhui Māori and Theme Leaders, has also honed research skills, and importantly, assisted researchers to work collaboratively with external industry and Māori partners. Equally, SfTI has resourced the building of relationships and common understandings required for effective collaborations. The Kāhui also sought to increase the perceived relevance of physical sciences and engineering for hapori Māori, and to explore how it could make a contribution to meeting Māori priorities and aspirations. All of these efforts have brought researchers and end-users closer together, increasing the opportunity for real world research impact.

*"What I hope happens beyond SfTI, what gets carried on from SfTI is this realisation that the connections between people are really where the knowledge resides, and we need to support and stimulate those connections, and we need to support people to figure out ways to build those connections. We should encourage and support people to look upwards and outwards, to look to their communities, to look to industry, to look to other scientists working in different kinds of areas, and not just pay lip service to that, but really support that with resource."*

There is also evidence that SfTI has led aspects of **best practice** that were subsequently emulated by other research institutions. The improved approach to Intellectual Property (IP) that accounts for mātauranga Māori and taonga species is one example of this. The new IP Management Plan, developed in collaboration with two Māori IP lawyers, and accompanying IP Policy and Principles has become a guiding light in countering standard IP laws that are not aligned with Te Ao Māori.

*"I was really pleased because of the recognition of taonga species, mātauranga Māori and where IP sits, it was great to have them push the boundaries as the first Challenge to come up with something. I think it set the scene in lots of different spaces. So, while it was done in the context of a SfTI project, it forced the university involved to think differently, and I think that for other projects, the expectation was high if those projects required it. It was an example - it wasn't in the too hard basket anymore."*

### How can we know these behavioural impacts have been achieved?

BNZIC has helped to create a more conscious approach and recognition of the experimentation that was carried out. It has also created the opportunity to identify positive factors and then share those with the rest of the science community to promote effective practices:

"*Because of the social science looking at what we're doing, when we did do something a bit differently, we at least started to collect evidence of, 'Did that work?' or 'How'd that go?' Whereas if we hadn't had that, we would have tried something and afterwards be none the wiser. So, we've got positive reinforcement for some things and obviously for other things that didn't quite work, we moved on*."

Throughout the life of the Challenge, BNZIC has purposefully followed the collaborative research process and analysed their observations, linking inputs and behavioural factors with outputs. This has made them uniquely qualified to understand what facilitates researchers to unlock the innovation potential of Aotearoa New Zealand. At the end of the first tranche, an Insights Report[30] revealed four key lessons:

1. Building openness is the key to collaborative innovation
2. Intermediaries are key catalysts of Vision Mātauranga
3. Success requires building the collaborative capacity of stakeholders
4. Ongoing communication brings the greatest benefit to collaboration

BNZIC's Tranche Two Insights Report[31] identified four factors that have been shown to accelerate innovation, evident in Aotearoa New Zealand and elsewhere:

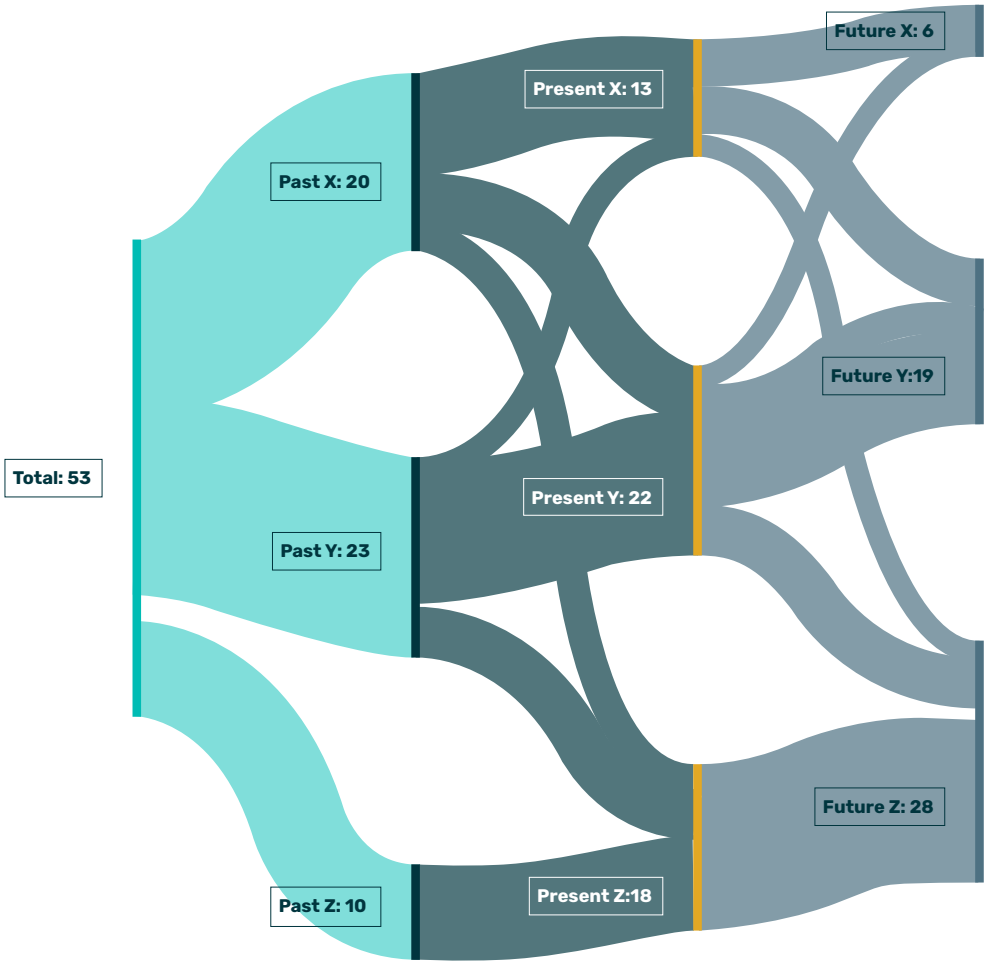
1. **Moving beyond Traditional Science** - This trend suggests innovation is accelerated when collaboration with non-scientists is promoted. This is done through a Mission-led approach to team design and the use of 'innovation intermediaries' to connect people throughout the innovation journey.
2. **Opening Science for Open Innovation** - Open innovation is a shift from more traditional and competitive closed practices. This collaborative approach involves finding ways to navigate the limits of intellectual property (IP) concerns and other barriers to open information sharing.
3. **Opening Science for Māori Innovation** - The Māori economy is a huge opportunity and strength for Aotearoa's science system. Supporting innovation means finding ways to open up the science system for mātauranga Māori and Māori scientists. This is promoted via removing barriers such as the current disproportionate weight of work on Māori scientists, concerns over ownership and use of Māori data and the need for 'Māori non-scientist matchmakers'.
4. **Developing entrepreneurial behaviours** - This trend involves providing support for scientists to develop the skills and capacity to collaborate well and make long term and authentic connections.

A recent recent BNZIC survey asked a sample of SfTI's researchers which of three science personas they most identified with in terms of their level of engagement with industry and communities. Persona X represents the 'traditional scientist' that does not engage, Persona Y engaged with industry and Persona Z engaged with communities (e.g. Te Ao Māori). Participants were also asked how this had changed from the past, in the present and looking ahead. Results indicated a clear shift away from Persona X, towards greater numbers of researchers identifying with Personas Y and Z in the current time, and anticipating continued movement into the future (see **diagram** on the next page).

30. Science for Technological Innovation. (2020). *SfTI Spearhead 1: Building New Zealand's Innovation Capacity. Phase 1 Insights.* https://www.sftichallenge.govt.nz/assets/Uploads/Our-research/Projects/Spearhead-projects/Building-New-Zealands-innovation-capacity/SfTI-BNZIC-Phase-One-Insights-Report.pdf

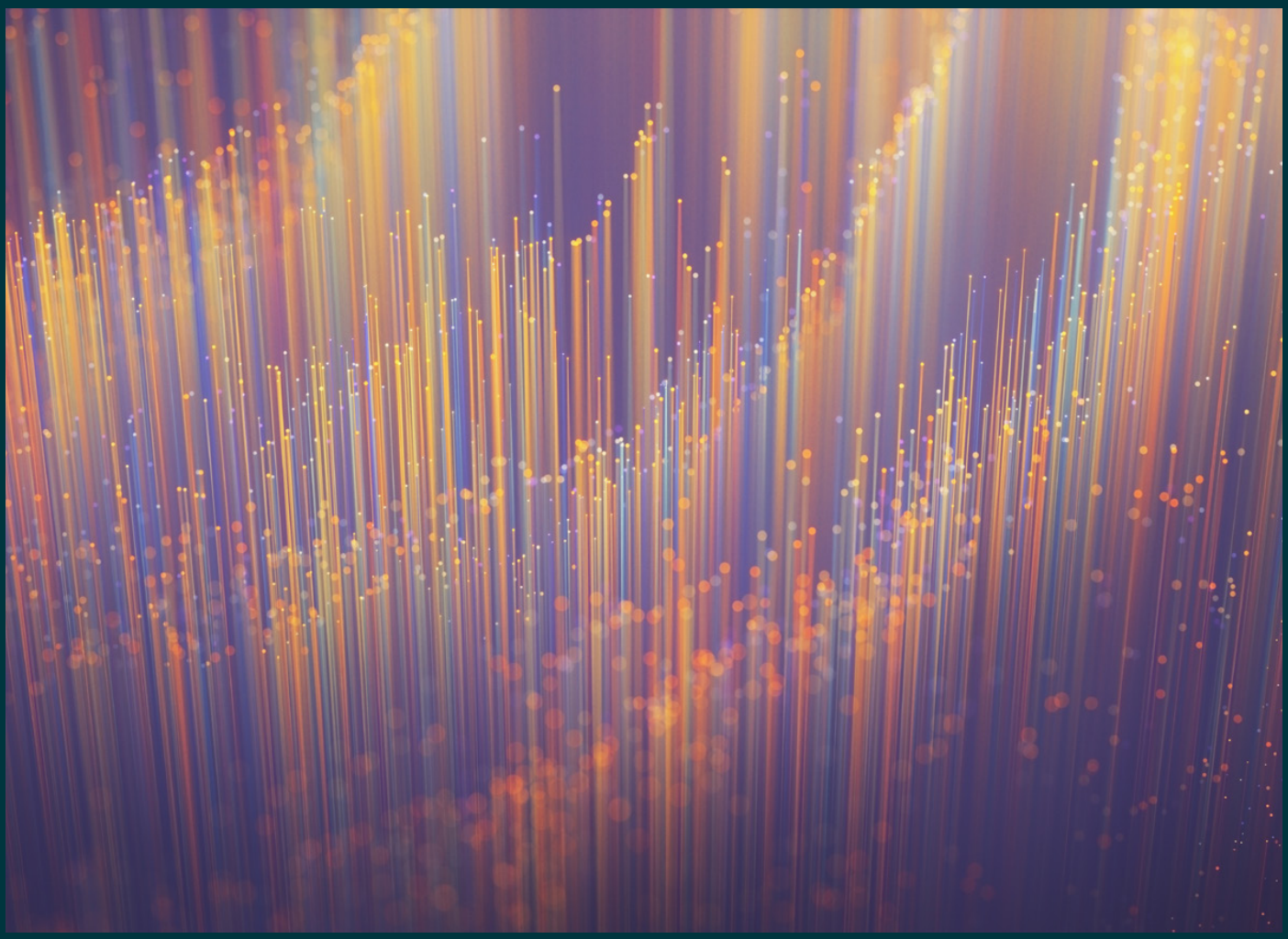
31. Science for Technological Innovation. (2022). He hiringa hangarau, he oranga tangata Building New Zealand's Capacity for Science-based Open Innovation. https://www.sftichallenge.govt.nz/assets/Uploads/BNZIC2022-FINAL-VERSION-13122022.pdf

## Development of Researchers' Capacity to Engage with Industry and Māori Communities




## FINAL THOUGHTS

The current document has provided many examples of the new processes developed and adopted by SfTI to achieve its Mission, and discussed how they have influenced researcher behaviour, leading to greater opportunities for impactful research. There are clear signals that investment in the SfTI National Science Challenge has resulted in benefits additional to those that may have been achieved had the funding been awarded to traditional research institutions, and this is in no small part due to the Challenge's emphasis on capacity development. Of course, only time will reveal the extent to which instances of input, output and behavioural additionality are capitalised on, but the expectation is that the SfTI community will take their cultural, leadership and commercialisation capacity with them into their future roles, and in this way, cannot help but influence Aotearoa New Zealand's RSI system for the benefit of all the people who call this place home.



# Appendices

# Appendix A

## SFTI TIMELINE

### 2014

Original SfTI Proposal submitted April 2014. Commencement Governance Group (CGG) established to oversee revision of the original SfTI Proposal and to provide interim guidance on Challenge direction.

'Sandpits' held to decide initial Spearhead projects. Three industry workshops are held across November and December 2014 to explore mission and direction of SfTI.

Interim Māori Working Party (IMWP) established to guide the development of SfTI's Vision Mātauranga implementation plan.

### 2015

**Personnel:** Stephen MacDonell becomes IT, Data Analytics and Modelling Theme Leader (replacing Mark Billinghurst), and Te Taka Keegan, already the Kāhui Māori Kaihautū, joins the Leadership Team.

Revised SfTI Proposal submitted in May, with funding approved two months later. Challenge launched publicly in September at event with 200 attendees. SfTI Collaboration Agreement with Partner organisations signed.

### 2016

**Personnel:** SfTI Board (John Bongard, Linda Cooper, Gottfried Pausch and Craig Ellison) convenes first meeting at which it formally appoints the SfTI Management Team, the Kāhui Māori, and Margaret Hyland as Director; a Communications and Stakeholder Engagement Specialist appointed (social media presence initiated, the first SfTI e-newsletter launches in July and SfTI website goes live).

**Research:** First group of five Spearheads commence: BNZIC; Inverting Electromagnetics; Medical Technology - Home and Community Care; Data Analytics Developing Industrial Decision Models; and Next Generation Additive Manufacturing. First Seed round: At least 20% of funding to be invested in VM-aligned projects. Ultimately, 76 proposals received $800K allocated across 10 projects, two successful projects having VM as their primary Theme.

## 2017

**Personnel:** Margaret Hyland resigns and Sally Davenport is appointed new Challenge Director, with Bruce MacDonald taking the newly established Deputy Director role; Science Advisors join the Board.

**Research:** Two New Spearheads begin: Precision Farming Technologies for Aquaculture; and Adaptive Learning Robots to Complement the Human Workforce. Second Seed funding round: 79 Proposals received with 18 being funded.

**Events:** The First Mission Lab (Industry Inspired Spearheads Workshop) is held in March 2017 to generate research priorities with Industry and Māori.

Four Spearhead Researcher Workshops are held in June 2017.

Te Taumata (a Māori Thought Leaders Group) formed to ensure project integrity.

Science Quality Review conducted in Oct 2017 by an international expert panel chaired by Colin Knox.

## 2018

**Research:** New Spearhead Ātea begins. Mission-design process for Spearhead Clean Water Tech begins. No Seed round is held in 2018.

**Events:** The second Mission Lab is held in April 2018; and the first Māori Data Futures Hui held at Te Herenga Waka Marae, Victoria University of Wellington.

He Ritenga, a Māori cultural pocket pamphlet created by the Kāhui, is produced and promoted at the NSC Parliamentary function.

Midway Review conducted.

## 2019

**Personnel:** Stephen MacDonnell appointed as second Deputy Director; Te Taka Keegan steps down from the Leadership Team to become an Ātea Project Leader; Kat Lintott joins SfTI's Board; Prof. Margaret Hyland joins SfTI's Science Advisors; Daniel Xu begins attending Board meetings as a Rangatahi observer; the Kāhui Māori welcomes two new members, Shay Wright and Kirikowhai Mikaere plus two Rangatahi observers, Te Rina Kowhai and Te Mauri Kingi, join the rōpū; and Enrico Tronchin recruited as SfTI's first Commercialisation Development Manager.

**Research:** The eight Spearheads undergo 'Refresh' Process. All are approved to continue, but Smart Services Spearhead, Tracks 1 & 2, are terminated.

The first round Seed Projects end and 21 new projects commence. Trial of Concept-Knowledge Theory with Dr Olga Kokshagina to form Veracity Tech Spearhead project.

**Events:** The second Māori Data Futures Hui is held in Te Aurere, Kaitaia, hosted by Tā Hekenukumai Puhipi (the late Sir Hector Busby) at his Whare Tātai Arorangi.

SfTI supports the creation of a FOMA Chief Adviser Innovation and Research and Stephen MacDonell becomes Technical Advisor to FoMA Innovation.

A Researcher e-Newsletter, Innovate, is launched.

## 2020

**Personnel:** Pauline Harris joins the Leadership Team and VM Theme co-Leader; Craig Ellison resigns from SfTI Board (and conducts first governance review); Jason Turuwhenua resigns from Kāhui and three new members join - Pauline Harris, Jeremy Banks and Vanessa Clark; Willy-John Martin leaves SfTI.

**Research:** Fifteen new Seed projects are contracted; and the VM Seed funding commitment increases from 20% to 25%. Mission-design process for Spearhead Biosecurity Tech begins.

IP Management Plan updated to better reflect Māori stewardship of Mātauranga Māori and taonga species.

**Covid impacts:** some SfTI events are postponed, cancelled or moved online; a range of research projects are delayed. Such delays continued over the next couple of years.

## 2021

**Personnel:** John Bongard (Chair) resigns from Board and is replaced by Linda Cooper, and new member Traci Houpapa is welcomed; and Shay Wright leaves Kāhui Māori.

**Research:** The three final Spearhead projects commence: Clean Water Tech (Feb 2021), Veracity Tech (July 2021), Biosecurity Tech - Detecting the Last Predator (Oct 2021). Researchers are invited to submit proposals to the final Seed funding round, and with the aim of increasing participation by women, Māori and Pacific researchers and Māori organisations, a Proposal Development Grant was offered to assist with proposal development. Due to the high quality of VM proposals, a total of 35% of the total fund was awarded to VM Seed projects.

Board approves Impact Acceleration Budget (IAB) for CDM to use to support moving projects closer to commercialisation – 11 eligible Projects receive funding in 2021 (3), 2022 (2), 2023 (4), and 2024 (2).

SfTI's Whakatauāki is gifted by Tā Pou Temara: *He hiringa hangarau, he oranga tangata, innovation in technology for the benefit of people.*

Several important pieces published: 'Understanding Māori Rights and Interests in Intellectual Property arising from Research' (report); 'He aronga takirua: Cultural double-shift of Māori scientists' (article); and 'He Pou Hiringa – Grounding Science and Technology in Te Ao Māori' (book).

With the assistance of the Commercialisation Development Manager, all Spearhead projects submit Commercialisation Plans to the Leadership Team and Board.

Second Science Quality and Impact Review (Oct 2021) chaired by Professor David Williams, assesses proposed Ending with Impact Projects (EWIPs) nominated by Spearheads.

## 2022

**Personnel:** Te Taka Keegan appointed Co-chair SfTI's Board, and Nancy Garrity steps in as the new Kāhui Māori Kaihautū. Kirikowhai Mikaere and Jeremy Banks resign from the Kāhui. Raewyn Tse is employed as Capacity Development Manager.

**Research:** Seven 'Ending with Impact Projects' (EWIPs) developed out of the Spearheads were approved.

Governance Review performed by BoardWorks.

Māori Innovation Delegation to CSIRO in Australia (with SfTI and FOMA representatives in attendance), with a key outcome being an Indigenous Trans-Tasman Strategic Alliance Agreement on Science and Innovation signed by representatives including the Prime Minister's Chief Science Advisor Aotearoa-New Zealand and Australia's Chief Scientist.

## 2023

**Personnel:** Reece Moors resigns as Programme Office Manager and is replaced by Raewyn Tse; new Commercialisation Development Manager, Deborah Crowe employed (within KiwiNet).

**Research:** Five Early Career Researcher (Rangatahi) Bolt-on Projects are funded.

SfTI launches new internal Ending with Impact Booster Funding mechanism - two Spearheads and four EWIPs receive booster funding.

Three additional EWIPs are launched: Te Pā Tūwatawata – An Indigenous Data Sovereignty Repository, Rongowai Flood Sensor Resilience Framework, and Improving Historical Map Imagery - in partnership with Parininihi ki Waitōtara (PkW).

**Events:** Final All of Researchers' Workshop held in Rotorua (Nov 2023).

Eight-part series of SfTI innovation video stories released.

## 2024

**Personnel:** Traci Hourpapa resigns from Board but is not replaced.

**Research:** The Impact Acceleration Budget (IAB) completed. Invested small amounts (mostly <$50k) to accelerate 32 projects. SfTI launches two new internal Ending with Impact funding mechanisms – the Impact Acceleration Fund (IAB) and the Rapid Response Fund (RRF).

NZIER Report reveals that SfTI research is likely to generate significant economic benefit in coming years.

SfTI short documentary 'Connected for Innovation' released.

Several legacy pieces completed: a SfTI legacy report, a Kāhui Māori legacy report and the final CD report; and BNZIC releases Māori and Science-based Open Innovation for the Benefit of People'.

# Appendix B

## SPEARHEADS

### Spearhead 1: Building New Zealand's Innovation Capacity

| | |
|---|---|
| Principal Investigators | Co-leaders: Urs Daellenbach and Katharina Ruckstuhl.<br><br>Omid Aliasghar, Maria Amoamo, Sally Davenport, Kirsty de Jong, Kiri Dell, Jarrod Haar, Maui Hudson, Madeline Judge, Merata Kawharu, Conor O'Kane, Paula O'Kane, Jesse Pirini, Rafaela Costa Camoes Rabello, Diane Ruwhiu, Sara Walton, and Paul Woodfield. |
| Team members | Colin Campbell-Hunt, Paul Tapsell, Jordan Waiti, Rebecca Downes, Sasha Grieg, Lawrence Green, Stephen Neal, Dominik Mann, Shirley Leitch, Manon Knapen, Susan Sandretto, Jeff Foote, Jamie Brathwaite, Annabel McKenzie, Louisa Choe, Jessica Mei Pung, Ella Akkerman, Quin Hartley, Gavin Walsh, Rogena Sterling, Olga Kokshagina, Tracey Cameron, Ashleigh Donaldson, Andrea Clark, Angela Davies, Nigel Brown, and Sophie Gimblett. |
| Host organisation | Victoria University of Wellington. |
| Partners | *Partners were research projects rather than organisations themselves.* |
| What was the intent? | The aim of the Building New Zealand's Innovation Capacity (BNZIC) research team was to examine the connections between Aotearoa New Zealand's physical science and engineering researchers and external stakeholders (specifically Māori organisations and communities, as well as businesses and commercialisation enterprises). The intent was to understand in greater detail how co-innovation actually happens. The view was that researchers have extra potential to be vital actors in a science-based open innovation system. However, for co-innovation to occur and generate benefits across stakeholders, critical foundational factors need to be in place at an individual and research team level, at an organisational level, and within the science system more broadly.<br><br>By tracking innovations in process and feeding back findings, observations and case studies during the Challenge timeframe, the BNZIC research team was able to identify when innovative processes were creating benefits, for whom, and if barriers continued to limit open innovation outcomes. Understanding how decisions and actions at the individual and team level of the science system can better respond to Māori economic and social aspirations was a central focus. Our research provides an evidence base for practices and pathways towards new sets of routines in the research and science sector. |

| | |
|---|---|
| What was achieved? | To date, across 2017-2024, BNZIC researchers have published over 30 journal articles, an edited book, *He Pou Hiringa: Grounding Science and Technology in Te Ao Māori* (which was chosen for the NZIER 2021 Summer Reading list for the Prime Minister), five book chapters and numerous conference presentations. The team has also published two insights reports making our research more accessible across policy and other decision makers, run workshops for researchers and research organisations, produced reports for government organisations (including the Productivity Commission and MBIE), presented and participated in fora for Māori, been actively involved in the iPENZ CRI research network, made contributions to Te Ara Paerangi, and submitted a Briefing to the Incoming Minister. Our research has also provided the foundation for a breadth of expert commentary in the media.<br><br>Our concepts and learnings have been taken up within organisations and various sectors across Aotearoa. For example, aronga takirua (the cultural double-shift issue identified by Jarrod Haar and Willy-John Martin) addresses the additional burden faced by Māori when guiding and navigating the cultural engagement of their teams while also completing their usual workload. Similarly, BNZIC research initiated with respect to intellectual property, Māori data sovereignty and the rights and interests of Māori partners in research in New Zealand has seen Maui Hudson and his collaborators, including Katharina Ruckstuhl, become international leaders on the design and implementation of traditional knowledge (+biocultural) labels as well as indigenous peoples' rights in data.<br><br>With international collaborators, we initiated a novel workshop to open and enhance the process of interdisciplinary team formation. Building from Concept-Knowledge (C-K) design principles such as knowledge mapping, concept exploration and mindful deviation, the workshop enhanced participants' willingness to creatively experiment across disciplines, provided a shared research directionality, and addressed many of the barriers to best team formation across organisations and scientific disciplines. Our longitudinal research also demonstrated how the availability of capacity development during research projects can focus greater entrepreneurial engagement and commercial orientation, as well as why engagement will vary across different phases of research projects. |
| What's next? | There remains a risk that learnings from innovations in the implementation of science (and science funding) will have limited impact on the design of future processes and approaches within the Aotearoa New Zealand science sector. The National Science Challenges experimented in order to overcome issues faced by their researchers and stakeholders. While BNZIC research demonstrated that behavioural change and benefits can be achieved through deliberate process change and building key capacities, behaviours may also quickly revert back due to entrenched practices and settings within the science system. While most new programmes will undertake some innovation, without incorporating social science in the research, both the design and the evaluation of the outcomes will be more limited. Communicating learnings is thus crucial. |

## Spearhead 2: Inverting Electromagnetics

| | |
|---|---|
| Principal Investigators | Ian Platt (supported by Ian Woodhead). |
| Team members | John Kennedy, George Chisholm, Michael Hayes, Bill Heffernan, Blair Bonnet, Ben Mitchell, Michael Frampton, Nicholas Long, Arvid Hunz, Joseph Bailey, Maui Hudson, Jordan Waiti, Colin Fox, Malcolm Morrison, Ian Platt, Ian Woodhead, and Te Awhina Arahanga. |
| Host organisation | Lincoln Agritech. |
| Partners | Taumutu Rūnanga, Seequent, and Takiwa. |
| What was the intent? | The research aimed to solve the problem of determining the spatially-averaged velocity of shallow groundwater, a vector for contaminants, culminating in a sensor system marketable to global regulators, farmers and consultants. The research was also framed to benefit Māori managing water quality, especially where mahinga kai is under threat from waterway contamination; a significant component of surface water is derived from groundwater.<br><br>Concomitantly, the research aimed to develop and promote Aotearoa New Zealand's capacity to use physical and engineering resources research, to generate export revenue via this country's high-tech manufacturing sector, and to benefit NZ-based regulators and farmers by enabling informed decision-making, land management and environmental foot-printing. |
| What was achieved? | Digital processing of the miniscule signals representing velocity used modelling and statistical techniques to minimise measurement uncertainty such that results from the lab-based sand aquifer correlated very well with water velocities within a useable range.<br><br>The very strong magnetic field necessary to elicit even miniscule signals from the very slow mm/hr groundwater velocities saw two approaches being devised. One surface-based and radically different arrangement comprised two coupled magnetic 'pipes', and the second (untested) arrangement promises increases in sensitivity at the expense of groundwater perturbation by the magnetic pipes.<br><br>New methods used in the electronic driver precisely controls the magnetic field capture energy from switching transients. This saves substantial power, enabling operation for more than one hour from a modest-sized battery, and enabled an order of magnitude increase in switching frequency, further improving the signal to noise ratio.<br><br>Christchurch-based global geophysical modelling and visualisation company Seequent visited the lab-based aquifer. This further built their understanding, for example, of how groundwater velocity measurements could be incorporated in their visualisation engine.<br><br>Many of the research findings, excepting IP-sensitive content, was reported more broadly in: B Mitchell, Y Zhou, M Hayes, B Heffernan, I Platt, J Bailey, A Hunze, N Long, I Woodhead (2022) Non-invasive groundwater velocity measurements using a novel electromagnetic flowmeter, *IEEE Trans. on Instrument. & Measurement*, 71(8):1-15. |

| | |
|---|---|
| What's next? | A complete pivot of this project was impractical since much of the science development was focussed on the somewhat unique set of science disciplines that converged to form the concept. Nevertheless, the science of electromagnetic detection of slow moving water bodies has been advanced, and the technology is poised for the next steps: applications where 0.1mm/s meet the specifications – and this does include measurement of groundwater velocity near sources and sinks (e.g. rivers), or advances in projecting large magnetic fields such as ex-fusion or ex-MRI research.<br><br>Some science has already been applied elsewhere. For example advances in potential measurement within liquids is being used within MBIE project UOCX2103, led by team member Dr Bill Heffernan.<br><br>The most promising spinout technology, not yet tied to a specific application, is energy capture and very precise magnetic field generation, for example, use in MRI. Possible linkages include existing contacts with Magritech, Spinsolve and inMR. We also have links to Harvard MRI specialists. |

## Spearhead 3: MedTech – Home and Community Care

Ending with Impact Project: Translating Disruptive MedTech Across the Innovation Chasm
Early Career Researcher Bolt-on: Better Diabetes care for whanau

| | |
|---|---|
| Principal Investigators | University of Canterbury: Geoff Chase, Volker Nock, Chris Pretty, and Lui Holder-Pearson. University of Auckland: Peter Hunter, Andrew Taberner, and Bryan Ruddy. University of Otago: Martin De Bock. |
| Team members | **University of Canterbury**: Jennifer Knopp, Cong Zhou, Jake Campbell, Jessica Fitzjohn, Steven Su, Rebecca Soffe, Jennifer HK Wong, and Linda Chen.<br><br>**University of Auckland**: Soroush Safaei, James McKeage, Chris McKinlay, Lisa Mravevic, Kathleen Antony, William Good, and Amy Chan.<br><br>**University of Otago**: Taylor Pearson and Geoff Shaw.<br><br>**University of Liege, Belgium**: Thomas Desaive, Vincent Uyttendaele, B Lambermont, and Julien Guiot.<br><br>**Furtwangen University, Germany**: Knut Moeller. |
| Host | **University of Canterbury** |
| Partners | Think Analytic, ASL Ltd, Globex Engineering Ltd, CanTec Ltd, Tiro Medical, Portal Instruments NZ, CDHB, Christchurch Hospital ICU, Respiratory Care Unit, Christchurch Diabetes Centre, Middlemore Hospital, and CHU de Liege, Belgium. |
| What was the intent? | The main goal was to develop human capacity and technology to improve and shift care of major high-cost chronic diseases from clinical locales to home and community care, and in doing so, to extrinsically change the economics of health care delivery, improve outcomes, and improve equity of access.<br><br>A specific goal was demonstration of platform technologies to enable automated care from advanced sensors and delivery devices, to model-based methods to close the loop and automate monitoring and care. These technologies should be low-cost to increase equity, but offer the same or better performance with open access to data and control.<br><br>The primary focus area was diabetes (type 1 and type 2), while the secondary focus area was respiratory disease. |

| What was achieved? | **Primary Focus: Diabetes** | **Secondary Focus: Respiratory Care** |
|---|---|---|
| | The diabetes research has achieved multiple outputs in the areas of:<br>• Model-based decision support has been improved, for example, subcutaneous<br>• delivery models created and proven in clinical tests, a digital twin model proven, and a subcutaneous insulin diagnostic test developed and validated.<br>• Three Insulin Sensing at Point of Care technologies developed.<br>• In terms of insulin delivery, jet injector technologies have been developed and tested and are on a path for commercialisation, and development and testing of two significantly lower cost insulin pumps.<br>• A light based glucose sensor has been developed and trialled, and venous oxygen saturation measurement has been improved, with trials of a new tool underway.<br>• There has been significant end-user and Māori input resulting in better technologies. | |
| | The respiratory research has achieved multiple outputs in the areas of:<br>A closed-loop ventilator was developed for Covid-19 and validated. In terms of sensor and monitoring technologies, the team developed 3+ specialised low-cost sensors to monitor breathing for in-patients and at home. A very low cost 'positive airway pressure' system run from phone and storing data in cloud was developed, plus a closed loop, wireless bedside system to control mechanical ventilation in ICU care<br>The team developed a spontaneous breathing digital twin, validated with in- and out- patients, as well as twins for chronic obstructive pulmonary disease and lung stiffness. | |
| | Multiple spinouts have resulted from the Spearhead, with | |
| What's next? | Several sub-areas of the research are in the process of accessing funding to progress commercialisation aims - to date, close to $1.4m has been awarded. Additionally, an Endeavour Proposal to the value of $9m and a KiwiNet application for $200k are pending.<br>All clinical testing needs to be finalised, however, there are more opportunities to leverage these platform technologies and methods to the maximum for improved outcomes, economic gain, and equity. | |

## Spearhead 4: Te Tātari Raraunga

| | |
|---|---|
| Principal Investigators | Puna Wano-Bryant, Andrew Mason, and Sydney Shep. |
| Team members | Marcus Frean and Adrian Poa. |
| Host | University of Auckland. |
| Partners | Parininihi ki Waitōtara Incorporation (PKW). |
| What was the intent? | Te Tātari Raraunga is a unique three-way research collaboration between the University of Auckland (UoA), Te Herenga Waka-Victoria University of Wellington (VUW) and Parininihi ki Waitōtara Incorporation, which catalyses innovation through new data science modelling and analytics in the context of mātauranga Māori, with the kaupapa of reconnecting missing Māori whānau for a prosperous economic, cultural, and socially revitalised future.<br><br>Missing shareholders are a major issue for Māori - it can be extremely difficult to find the information about whānau lands due to intergenerationally lost knowledge, disconnection from iwi, hapū and whānau, as well as intergenerational trauma due to colonisation. Current systems are available, but only if lands have been succeeded and correct names are available. For Māori, names are often changed for various reasons or nicknames are used. Te Tātari Raraunga used matching and inference techniques to find missing shareholders, inferring relationships between different people and groups that account for identified issues and nuances for Māori. This project has a powerful impact for Māori, economically, in terms of whakapapa and spiritually, enabling connection back to their whenua, people and whānau. Additionally, this system is applicable to many other areas that could be commercialisable outside of the Māori Social enterprise space it currently resides in.<br><br>While a single project in terms of design and reporting, the Spearhead had two clearly distinct but complementary work streams, led by Andrew Mason UoA, and Sydney Shep for VUW.<br><br>Te Herenga Waka-Victoria University of Wellington's successful application to the SfTI Rapid Response Fund in Tranche Two enabled the continuation of their TRIPLY SaaS subscription, and Impact Acceleration Fund support enabled the team to create a project Roadshow, including video content to help socialise the work and opportunity. |

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|---|---|
| What was achieved? | By formally bringing PKW into the project as co-researchers, the team developed an MOU, an IP/NDA agreement, a Māori Research Data Management Plan, and a Mātauranga Māori quality assurance framework. The highly productive cross-disciplinary and multi-iwi research team includes engineers, linguists, developers, historians, econometricians, and postgraduate students from UoA, VUW, and PKW.<br><br>In terms of applications, the tools developed are *kari*, *matangaro* and *mahere*, although these names changed as they were developed. *Kari* users are able to find interconnected data about owners, trusts/incorporations, and landblocks.<br><br>A separate, small-scale Ending with Impact Project developed and demonstrated a prototype tool to enable direct annotation of historic map images by members of Parininihi ki Waitōtara. As this technology improves, identifying, contacting and engaging missing whānau through Māori Data Science will contribute to the enormous challenge for Māori Incorporations, Land Trusts, and iwi and hapū, and lead to economic, social, and cultural revitalisation.<br><br>Across the two Universities more than a dozen research students were supported, along with undergraduate and summer students, and this reflects major capacity and capability developed in the team. |
| What's next? | The VUW team is holding hui around the motu to discuss opportunities for alternative investment sources that would allow the research to continue, and perhaps find alternative applications. It may be possible to commercialise the inference work to help support social enterprise mahi with iwi Māori, making it more economically sustainable.<br><br>The University of Auckland team has continued to develop their inference pipeline to handle new data sources, and are also publishing and publicising their work in scholarly venues. |

### Spearhead 5: Next Generation Additive Manufacturing: Additive Manufacturing of Biomaterials

| | |
|---|---|
| Principal Investigators | Co-leads: Kim Pickering (UoW) and Florian Graichen (Scion). |
| Team members | **RA1** Co-leads: Sonya Scott (Agr), Laura Domigan (UoA), and Sarat Singamneni (AUT). **RA2** Co-leads: Tim Miller (VUW), John Kennedy (GNS), and Mark Battley (UoA). **RA3** Co-leads: Johan Potgieter (Massey), Marie Joo le Guen (Scion), and Jerome Leveneur (GNS). **Ending with Impact Project**: Yifan Lv (Sarat Singamneni- mentor) (AUT). **Rangatahi Bolt-on Project**: Heiana Agnieray (AUT).<br><br>Overall the team consisted of at least 40 researchers joining the three-monthly meetings over the period 2014 to 2022. |
| Host | Scion. |
| Partners | All eight partners (Scion, Agresearch, GNS; UoA, AUT, UoW, Massey, VUW) co-funded projects carried out by people in their organisation. Over the life of the Spearhead, a large number of industry and Māori partners participated via formal annual Industry Days. |

| | |
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| What was the intent? | The Spearhead focussed on potential globally disruptive science in Materials, Design and Manufacturing, leveraging Aotearoa New Zealand's advantage in biobased solutions.<br><br>It intended to achieve this through bringing together researchers who were early adopters of additive manufacturing (both 3D and 4D printing) and to create biomaterials for application. Design-led approaches were used to experiment with collaboration, for example, during quarterly, multi-day lab visits.<br><br>Commercialisation of additive manufacturing technology was also a goal, alongside a general drive to enable a high value bioeconomy in this country. |
| What was achieved? | A diverse team was assembled with different backgrounds in science, technology development and design, and ultimately worked well together to created leading edge concepts and exemplars that were then picked up either by their institutes and developed further, or by industry, for example, prosthetic manufacturing, new electronics, and ways to use responsive materials to redesign concepts and products.<br><br>Industry Days were effective in bringing together researchers and users of research to ideate and talk without pressure.<br><br>The team created a 'toy' out of SfTI's first logo to illustrate the various new ideas being tested. The dodecahedron was initially a design challenge, then became a biomaterials demonstrator, then illustrated various new ways to make an object that was responsive to different stimuli. This was presented at different times to ministers to showcase what's possible. Other demonstrator products were also created and demonstrated.<br><br>A database of materials, including their characteristics and performance, a database of different additive manufacturing equipment, both commercial and modified or developed by the team, and a database of responsiveness challenges for 4D printing applications was created and shared across the team.<br><br>A number of students were also exposed to a different way to consider manufacturing and biomaterials. In addition, several of the team were part of successful MBIE bids to progress concepts and prototypes created in the Spearhead, while others were part of aligned programmes of work, and at least three team members are now working in related start-ups.<br><br>The majority of the large team attended capacity development activities and participated in KiwiNet events.<br><br>As a result of this research, Aotearoa New Zealand was globally visible in the additive manufacturing field via publications and presentations at a time when this technology was very new.<br><br>The EWIP (Shape-shifting Meta-surface Reconfigurable Antennas for Better Wireless Communication) and RBOP (Remote controlled smart sponge for precision plant care) were extensions of the original research (see below). |

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| What's next? | The Spearhead finished in 2022, and most of the team have continued to work together in some manner, many within other SfTI research.<br><br>The **EWIP** is continuing the work to manufacture shape shifting antennae to improve wireless communications using 4D printing alongside three New Zealand companies. Metamaterials and their configuration allow reduction in antennae size while maintaining or growing performance, and such technology will be vital for 5G-6G applications.<br><br>In a similar manner the **RBOP** is exploring an application in orchid farming where water monitoring through developing a water responsive shape shifting sensor will make moisture control more efficient and specific.<br><br>Both projects are expecting to continue in some form via other funding mechanisms.<br><br>The spearhead enabled significant collaborative capacity to develop within Aotearoa New Zealand across Universities and CRIs, and has enabled future technology developments to continue. |

### Spearhead 6: Adaptive Learning Robots

Ending With Impact Project: Forest Surveying Robot
Rangatahi Bolt-on Project: Robots That Learn

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| Principal Investigators | Armin Werner, Will Browne, and Johan Potgieter. |
| Team members | Heath Ascott-Evan, Tony Cui, Beth Cutler, Jaco Fourie, Chris Graham, Chris Hamling, Ben Hart, Kane Hodges, Nick Huang, John Jia, Elijah Kahuroa-Stainton, Megan Leung, Craig Martin-Smith, Brendan McCane, Josh McCulloch, Steven Mills, Puja Nory, Jean-Henri Odendaal, Violet Ong, Afereti Pama, Abubakar Siddique, Emily Stiener, Gabby Summer, David Valencia Redrovan, Koen Van Rijnsoever, Gaopeng Wang, Zhan Widdison, Henry Williams, Bowen Xiang, Raining Xing, Hoda Yamani, and Brendan Zhou. |
| Host | Lincoln Agritech Ltd |
| Partners | Wrybill Robotics, Lake Taupo Forest Management, Lake Taupo Forest Trust (Patrick Nepia and Geoff Thorp), Kaumatua Tuhoe (Chaz Doherty), Ngati Whare Trust (Vale Ruri), Ngati Whare Holdings (Earl Rewi), Te Pua o Whirinaki Regeneration Trust, and the cooperation of Ngāti Whare and the Crown. |

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| What was the intent? | The Spearhead aimed to create adaptive learning robotics technology and robots, including a number of deliverables:<br>1. Algorithms, models and software to analyse multiple sensor data towards task-relevant objects, together with relevant hardware specifications, including adaptive perception.<br>2. User interface into voxel-based 3D/4D maps under the Robot Operating System (ROS).<br>3. Software modules to enable robot-learning of probabilistic inferencing in environmental interactions.<br>4. Adaptive algorithms and software that rapidly identify actions that a robot is capable of performing and that are appropriate to the task.<br>5. Hardware models that show how to adapt robot morphology 'on the fly'.<br>6. Methods to inform the adaptive behaviour and learning control of robots related to dynamic safety aspects when completing tasks with high-speed movements in human workspaces.<br>7. Robotic platform demonstrators that integrate the project algorithms through software as well as adaptable hardware on a mobile platform for safe task execution in two realistic environments. |
| What was achieved? | In terms of technical outputs, software, hardware, sensing, models and communication for outdoor adaptive robotics, were applied via a demonstrator of a forestry path-clearing robot. The project created three test beds for researching dexterous manipulation tasks through machine learning. It also developed a simulated and real-world test bed for researching autonomous racing using F1Tenth cars.<br>The Spearhead brought together a large New Zealand-wide team: a total of 11 research assistants, ten part IV students, six summer research students, four masters, and five PhD students from three universities have been directly involved in this project. Two Māori/Pacific Island students and seven female students comprised participated.<br>A total of 11 papers have been submitted and/or published, with numerous others in the pipeline. |
| What's next? | Forestry is a niche area but there is keen interest in robotic technology in such a difficult environment, not least because companies are interested in substituting robots for labour - the more autonomy a vehicle has, the less labour is required. Use examples include: weeding young tree plantations, cleaning rubbish/slash from between tree-rows, mulching debris as fuel reduction in fire risk management, and carrying LiDAR sensors through nurseries for tree sizing.<br>The markets are pushing for these types of features, however, none of the current manufacturers have yet worked on implementing this type of technology for difficult operating environments such as forestry. As well as the interest from forestry operators in New Zealand, there is already interest in using the field robot in Australian forestry conditions. An unexpected use case there is carrying sensors for spotting koalas during tree harvest.<br>The commercialisation options currently being explored include a JV between the researchers and partner organisations, which will license commercialisation rights to industry partners based on sector and territorial reach. This provides a 'franchise' type model to enable scaling beyond forestry and into other sectors, and beyond New Zealand and into global territories.<br>The research into robotics for complex environments and dexterous manipulation is ongoing. Two undergrad research assistants have begun postgraduate studies with university funding and will continue the 'Robots that Learn' research.<br>The intellectual property rights and technology development skills to continue producing new robotic solutions for industry remain in New Zealand. |

## Spearhead 7: Precision Farming Technology for Aquaculture

Ending with Impact Project: Ocean Intelligence
Ending With Impact Project: Autonomous Underwater Vehicle for Ocean Survey

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| Principal Investigator | Chris Cornelison |
| Team members | Ross Vennell, Paul Barter, Shaun Ogilvie/Heni Unwin, Max Scheel, Shaun Graham, Dana Briscoe, Sara Jamieson (Project Manager), Mengjie Zhang, Bing Xue, Abigail McGhie, Ying Bi, Zhiheng (Dylon) Zeng, Richard Green, Andreas Willig, Kelvin Barnsdale, Ori Ganoni, Oliver Batchelor, Josh McCulloch, Brian McMath, Johan Potgieter, John Futter, Cather Simpson, David Williams, Neil Broderick, Mary Sewell, Nina Novikova, Alex Risos, Isabelle Williams, Hannah Matthews plus Post-docs and Masters and PhD students. |
| Host | Cawthron Institute. |
| Partners | Various partners have been involved throughout the life of this Spearhead. |
| What was the intent? | The Precision Farming Technologies for Aquaculture project aimed to develop novel technologies in sensing, communications, and data analytics that will transform Aotearoa New Zealand aquaculture from its traditional experience-based mode of operation to one that is high-tech and knowledge-based. Research is focussed on (i) integrating Vision Mātauranga and developing a pathway for commercialisation in collaboration with industry; (ii) developing imaging sensors using machine learning, enabling farmers to 'see' their farm from their computer or mobile device; (iii) development of inexpensive, practical Internet of Things (IoT) sensors that can be easily deployed; (iv) developing field-based photonic sensors that enable detection of the amount of food and nutrients in the water; (v) developing an affordable ROV with assisted automation to enable farmers to rapidly inspect their farm crops and structures; (vi) developing underwater wireless video stream from an untethered ROV; and (vii) data engineering to develop a data visualisation and intelligence system that can be used on a farmer's desktop or mobile device.<br><br>This is a highly competitive market which is growing fast. Many nations are investing heavily in fish farming since it offers major potential. Growth in aquaculture technology is expected to be nearly 15% per annum over the next 5 years. Advances created through this Spearhead will be a critical part of assisting the industry in its growth ambitions and its ability to develop farms 1000s of hectares in size in open seas. |

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| What was achieved? | A team was brought together from a number of institutions, and although initially somewhat siloed, greater interaction did develop despite disruptions due to Covid. Relationships with the sector and iwi were similarly developed over time. Good progress was made with the formation of an AquaTech/Innovation forum and it was passed onto industry to lead (i.e. Aquaculture NZ and the Marine Farming Association).<br><br>The programme trialled a number of sensor systems for farm monitoring via the Novel Environmental Sensor Technology (NEST) floats – temperature, climate, lights, buoy "load", waves and mussel health. Good progress was made in developing communication systems to transfer data back to land including underwater within the vicinity of the farm.<br><br>An Automated Underwater Vehicle (AUV or ROV) was developed that could navigate mussel ropes reliably for more than 80m in currents up to 1 knot. Further, software to count/size/type mussels was developed and demonstrated. This technology, including underwater communications via BiFi, has significant promise for aquaculture as well as other marine inspection tasks. This research created the basis for the Autonomous Underwater Vehicle for Ocean Survey (AUV) EWIP where it will be refined.<br><br>The Ocean Intelligence EWIP is combining customised sensors and data analytics to optimise existing farms and enable expansion into large-scale ocean farm management. It aims to maximise impact in the form of greater access to data-driven knowledge by stakeholders. MacLab and Ngāti Rārua have bcome active partners in the EWIP.<br><br>A combined Raman and Hyperspectral sensor system that could measure phytoplankton in seawater was also developed. While successful in the lab, portable field instruments remain expensive and impractical and so such a sensor is still a long way from being useful. At the same time, some progress towards using AI/ML to automatically identify farm features from video was made and holds promise for the future. Refinement of the method and, hopefully, technology transfer will occur via the Data Science for Aquaculture SSIF programme (2020-2027). |
| What's next? | The data rich management of aquaculture farms is progressing via the Ocean Intelligence EWIP, building on the experience with IoT sensors plus relationships developed with Oceanum and iwi partners. The farm image analysis research may later be added to a platform being developed by the EWIP.<br><br>The Remotely Operated Vehicle (ROV) has significant commercial promise and should be progressed by Richard Green and the University of Canterbury after further refinement via the AUV EWIP. The first applications may not be in aquaculture, but rather, for wharf or ship inspection. Similarly, the phytoplankton sensor may have applications outside aquaculture e.g. scientific environmental monitoring. |

## Spearhead 8: Ātea

Ending With Impact Project: Your Ātea NLP Platform
Ending With Impact Project: Virtual/Immersive Wānanga
Early Career Researcher Bolt-on Project: Matariki Hunga nui Mixed Reality Experience

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| Principal Investigators | *Ātea*: Hemi Whaanga.<br><br>*Your Ātea NLP Platform*: Leads: Hēmi Whaanga and David Bainbridge.<br><br>*Virtual/Immersive Wānanga*: Leads: Hēmi Whaanga, Rob Lindeman and Holger Regenbrecht.<br><br>*Matariki Hunga nui Mixed Reality Experience*: Kris Tong, Noel Park, Tiriana Anderson, Hemi Whaanga (with additional team members: Stu Duncan, Iauri Lloyd-Jones, Ryan McKee, Kimiora Whaanga, Dean Whaanga, Tirian Anderson, and Rory Clifford).<br><br>Also involved were three Postdocs, two PhDs, five Masters students and five interns. |
| Host organisation: | Waikato University |
| Partners | Ātea partner: Te Rūnanga ō Awarua, Te Rau Aroha Marae<br><br>EWIP partners for Your Ātea NLP Platform: Te Nehenehenui (Maniapoto Tribal Settlement Entity), Ian Grover (Ngāi Tahu Holdings - Karahi Matai Whenua), Corey and Dr Gerard O'Regan (Pouhere Kaupapa Māori - Otago Museum), Rauawaawa Kaumatua Charitable Trust, Okapu Marae, Waipapa Marae Trust, Te Ahoroa Marae Trust, Ngā Marae Tōpū and Te Whakakitenga o Waikato.<br><br>EWIP partners for Virtual/Immersive Wānanga: Ian Grover (Ngāi Tahu Holdings - Karahi Matai Whenua), and Corey and Gerard O'Regan (Pouhere Kaupapa Māori - Otago Museum),<br><br>Matariki Hung Nui partner: Te Rūnanga ō Awarua, Te Rau Aroha Marae. |
| What was the intent? | The intent of Ātea was to broaden, incorporate and develop new and creative digital technologies for stretched science and to engage a broader range of Mātauranga-a-iwi, language, teaching, histories and knowledge, to create a virtual, digital space in which Māori knowledge can be created, articulated, interpreted, interrogated and built. This spearhead aimed to connect Māori, iwi and communities that are increasingly global. Its overall goal was to conduct impactful and meaningful research with experts in artificial intelligence (AI), virtual and augmented realities (VR & AR), mixed realities, machine learning (ML), leading Māori academics engaged in Indigenous data sovereignty and digital repositories, Māori industry partners, tohunga, iwi, rangatahi and collaborators.<br><br>EWIP 1 Intent - Your Ātea NLP Platform: Develop Māori-designed and governed systems to enable whānau, hāpu and iwi to interact with their data using te reo Māori.<br><br>EWIP 2 Intent - Virtual/Immersive Wānanga : Develop a flexible system that enables individuals and groups to meet virtually and discuss issues via low- and high-tech tools, as well as corresponding appropriate cultural protocols.<br><br>Rangatahi Bolton Intent - This project aimed to co-design and collaborate with Te Rau Aroha Marae and tātai arorangi, and Māori astronomy experts on Matariki using immersive technologies. As an outcome of this project, a mobile platform-based tātai arorangi MR experience will be built using the captured content. The haukāinga will evaluate this experience and provide feedback on the usability and appropriateness of Matariki knowledge in this medium. A set of content creation guidelines and tools will be shared with communities to assist the production of similar immersive content of their own. |

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| What was achieved? | Ātea achieved the following 4 projects:<br>1. Created an open-source digital library architecture with user authentication and access that supports multiple membership of iwi/hapū/whānau.<br>2. Te reo Māori voice to text systems. Software tools were built that can refine and store Māori medium knowledge from video, sound recordings and written text in digital format.<br>3. Integrated tele-co-presence system, which allows two remote parties to meet in the virtually reconstructed wharenui, and includes storytelling experiences.<br>4. Constructed a framework of guiding principles for future generations to interact safely in these developing technologies.<br>EWIP 1 developed NL tools for Te Reo, and associated relationships for creating impact.<br>EWIP 2 developed virtual interaction tools for Te Reo, and culturally appropriate, and associated relationships for creating impact.<br>Matariki Ahunga Nui developed a Matariki virtual experience with 360 video and 3D Voxelvideos. |
| What's next? | The teams are seeking to engage in more development and handover to others to support the work.<br>Matariki Ahunga Nui requires for work, for example a moving star background, improved resolution and improved filming techniques that will lift the quality of the project before it can be released. |

### Spearhead 9: Clean Water Technology for restoring the mana and mauri of waterbodies

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| Principal Investigator | Aisling O'Sullivan. |
| Team members: | Aisling O'Sullivan, Hossein Najaf Zadeh, Stuart Lansley, Benoit Guieysse, David Barker, Rupert Craggs, Kim Pickering, Hossein Kien Tat Wai, Ricardo Bello Mendoza, Dan Bowles, Campbell Stevens, Alice Loretto, Florencia Ocampo Prieto, and Sumaira Bashera. |
| Host organisation: | University of Canterbury |
| Partners | Pōhara Marae (Waikato, Ngāti Korokī and Ngāti Mahuta), Koukourārata Marae (Ngāi Tahu), and the Hamilton waste water treatment plant. |
| What was the intent? | To help meet government's ambitious targets to reverse water quality pollution, especially from nutrients, by 2025 through the development and application of innovative and bold technologies that embed Te Mana o te Wai values into their design.<br>The project aimed to develop new water treatment products demanded broadly in Aotearoa New Zealand and overseas. Engineered materials could help overcome the shortcomings of conventional adsorbents and bio-carriers. Ideal media will have (i) optimal geometry (e.g. high specific surface area via complex porous pathways) and (ii) bespoke chemistry (e.g. hydrophilicity, carbon availability, and biocompatibility) providing enhanced functionality as an efficient adsorbent, C-source and/or bio-carrier. These optimised and multi-functional attributes would be possible by taking advantage of recent advances in bio-fabrication and 3D printing. |

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| What was achieved? | Capability was built through supporting summer students and post-graduates. In addition, a Māori Project Coordinator was contracted to assist with analysis of the 314 responses to PhD student Honor Columbus' survey: Water Wellbeing Perspectives and Priorities in Canterbury Waitaha.<br><br>Engagements included visitors from Wairewa Rūnanga (Ngāi Tahu) to understand the project's kaupapa and technology including 3D screen printing, while the team visited Wairewa and the NIWA water treatment field trial installation at Te Kopua Whānau Campground in Raglan.<br><br>During the programme, and as guided by our Science Advisory Group, the focus narrowed to small-scale filters for removing nitrates from drinking water, and bio-based biocarriers for small-scale wastewater treatment facilities. Initial Lean Canvas assessments included further understanding of problems and design constraints with current technologies, scale of the field, targets/metrics/ efficiencies, managing end-of-product-life, and detailed design and cost analysis.<br><br>There were several technical achievements. First was f*unctionalisation* - through new formula for functionalisation of bio-materials, an order of magnitude increase in adsorption capacity of nitrates was achieved, which exceeds the commercial resin used as a benchmark at the same dosage. Second,<br><br>*Manufacture/scale-up* - the goal of commercially-viable manufacture was unachievable with standard 3-D printing, so for filters, automated and scalable screen-printing was developed, and this advance provides a suitable pathway to develop a mass production process. |

What's next?

An independent business analysis was commissioned to further define post-research strategy, which may involve PSAF commercialisation funding via KiwiNet, and pilot scale field trials with early adopters, e.g. marae trusts, DOC and councils. The independent analyses included substantive background material and context, and identified business models and commercialisation considerations.

### Bio-based Biocarriers

The Moving Bed Biofilter/Biofilm Reactor (MBBR) is the most effective technology for reuse/recycling filter material. However, leakage into the environment has increased aquatic contamination and in some cases, death of animals and birds by ingesting plastic biocarriers. Nevertheless, while MBBR is likely to be a very lucrative market, biocarriers face fierce competition from inferior but cheaper HDPE carriers. Adoption of biodegradable biocarriers is directly linked to MBBR adoption, currently modest in NZ/ Australia due to well-established waste water treatment plants (WWTP) and increasing cost pressures. Nevertheless, MBBR adoption is expected to increase because of increasing community/government environmental pressures.

The cumulative 25-year value of the potential municipal biocarrier market is estimated at $36.94m for NZ and NZ$246.61m for the Australian market, and respectively NZ$76.87m and NZ$8.00m for domestic plants.

Licensing to an existing market leader seems optimal. Strategies include exclusive licensing to an established global MBBR manufacturer (e.g. Veolia), or exclusive or non-exclusive licensing to manufacturers/installers of MBBR septic tanks.

Successful commercialisation depends on efficient, effective and economic supply chains. It must mitigate supply risk by including alternate leaf fibres, and requires economically manufacturing the biocarrier at scale, competitive with current HDPE carriers, e.g. by identifying a local manufacturer to invest in 'tooling up'.

### Nitrate filters

The new technology's key point of difference is environmental sustainability, hence intersecting the global nitrate removal systems market (US$2b by 2026) and the mass-produced, high-volume, low-value ion-exchange resin (US$523m by 2024). Sustainability is an emerging water purification trend, so licensing to an existing market leader is likely to be the optimal pathway to market.

While the industry partner will ultimately handle regulatory compliance, NSF/ANSI 61 Drinking Water System Components – Health Effects (USA) and FDA Regulation 21 CFR 173.25 (USA), it's essential for interim R&D to align with performance and regulatory standards for the target markets.

## Spearhead 10: Veracity Technology Enabling End-to-End Veracity within Value Exchange Ecosystems

### Early Career Researcher Bolt-on Project: Building Rangatahi Veracity Capacity

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| Principal Investigators | Matthias Galster (UC) and Tim Miller (VUW). |
| Team members | Kelly Blincoe, Ewan Tempero and Judith Perera (UoA); Maui Hudson, Te Kahautu Maxwell and Steve Reeves (UoW); Kevin Shedlock, Kirita-Rose Escott, Jens Dietrich and Markus Luczak-Roesch (VUW); David Eyers and Stephen Cranefield (UoO); Brendan Hoare (buypure nz); Danielle Lucas, Ernestynne Walsh and Shanara Wallace (Nicholson Consulting). |
| Host | Victoria University of Wellington |
| Partners | RUSH Digital, Organic Winegrowers New Zealand, Catalyst Cloud, Āhau, National Library of New Zealand, various government agencies |
| What was the intent? | The Veracity Technology project undertook research and development on the modern digital technologies needed to build a secure, scalable, reliable and resilient socio-technical approach that closes veracity blind spots at the transaction and interaction points within decentralised value exchange ecosystems. In this context, veracity encompasses trustworthiness, truthfulness and authenticity. The research was organised into three core research streams: conceptual and regulatory, computational, and socio-technical. A fourth work stream integrated research outcomes from the first three streams into one coherent infrastructure testbed. |
| What was achieved? | The team have co-constructed the "Ko te taiao matihiko" (the digital environment) concept model of veracity and have translated this model into a formal, provable logic for veracity that universally applies to value exchange ecosystems, in both the real and virtual worlds.<br><br>A number of prototype tools have been built to demonstrate how provenance information can be stored alongside software products, tracking how it has been built and changed over time and by whom, and to detect, classify and address software supply chain vulnerabilities.<br><br>A novel classification of veracity requirements relevant to software systems has been built, which also identifies the concept of veracity technical debt. Working with partners RUSH Digital and Organic Winegrowers NZ, the team used the classification to identify veracity blind spots in the organic wine supply chain. They also constructed a prototype app to automate the delivery of Overseas Market Access Requirements (OMAR) notifications.<br><br>Additionally, the team investigated how the concepts of veracity apply to artificial intelligence (AI), developing mechanisms to enable AI-generated decisions to be contested by those affected by such decisions.<br><br>Work has been undertaken with iwi Māori and kura to create ngā pātaka raraunga, or data storehouses, built specifically to meet the needs of young Māori. The potential utility of AI and blockchain technologies in the Galleries, Libraries, Archives and Museums (GLAM) sector has also been investigated. |

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| What's next? | The team will continue to enhance the software provenance and OMARs demonstrators mentioned above, in partnership with industry and users.<br><br>Building on work conducted in this Spearhead, a subset of the team plus others have submitted a four-year Research Programme proposal focused on fortifying local and global software supply chains to the MBIE Endeavour Fund.<br><br>The team is continuing to engage industry, Māori and government agencies, regarding opportunities to further develop digital solutions for the organic wine supply chain, albeit the underlying technologies will be applicable to many other export-oriented sectors. RUSH Digital remain an active partner in this work.<br><br>The Spearhead work has helped to highlight that the lack of a national data infrastructure means there is an ongoing risk that solutions are not built to interoperate. Working with the support of Catalyst Cloud, the team is considering whether they might submit another MBIE Endeavour Fund Research Programme proposal centred around this challenge in 2025.<br><br>The team is also currently exploring the potential of a business built around the provision of veracity knowledge and technologies, drawing on the research base created through the Spearhead project but augmented by more of a consulting arm. |

### Spearhead 11: Biosecurity Technology: Detecting the Last Predator

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| Principal Investigators | Co-leads: Katerina Taskvoa (UoA); and Tara Strand (Scion). |
| Team members | Chaz Doherty, Mereana Taungapeau, Jamie Bell, Bruce Warburton, Yi Chen, Simon Knopp, Jess Kerr, Alvin Valera, Yau Hee Kho, Jyoti Sahni, Liam Brydon, Sandra Gomez Galvez, Rob Whitton, Michael ZiQi Lu, and Lachlan McKenzie.<br><br>Six Pūhoro STEMM Academy Interns, summer interns, Iwi collaborators, and research assistants also contributed. |
| Host | University of Auckland. |
| Partners | Scion Research, Victoria University Wellington, Manaaki Whenua, Boxfish Robotics, Lincoln Agritech, Ngāi Tūhoe, Predator Free 2050 Ltd (PF2050), Biological Heritage NSC, and Cacophony.<br><br>Industry Advisory Board: Cameron Baker, Dan Tompkins, Andrew Kralicek, and Catherine Duthie.<br><br>Other stakeholders and advisors included: Brent Beaven, Programme Manager/Director PF2050, DOC; Viki Heta, Kaitiaki Northland Biosecurity; Lisa Forrester, Northland Regional Council; Robyn Kannemeyer, Manaaki Whenua Landcare Research; Andrew McConnell, Kiwifruit Vine Health and former ranger; Shaun Holland, Pest Free Kaipara; Waata Papali'i-Smith, Josh Wardle and Chelsea Bridgman, MPI; Lindsay Barber, Tasman District Council; Bec Simpson, Brent Barrett and Helen Blackie, Boffa Miskell; Desi Ramoo, Director B3; Ngāio Matariki Osborne Mace, former ranger; Heke Doherty, former ranger; and Oscar Fernandez, industrial designer from Tūhoe. |

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| What was the intent? | The intent was to create a swarm of smart networked sensors (associated with drones) using artificial intelligence to decide if each sensor is in the right position to detect/observe predators. If an individual sensor does not detect a predator it will seek knowledge from the collective intelligence to determine where to move (or be moved) to for optimal detection.<br><br>As for PF2050, predators are defined as rats, stoats and possums, but in aligning with and enabling PF2050, the technology may be adapted for other unwanted pests such as wallabies and some insects. The key target is the last scarce and well spread out predators in Aotearoa New Zealand's forested and complex terrain, to enable complete eradication.<br><br>The Spearhead's target was to deliver a proof of concept via new technology with trials to demonstrate the potential value in difficult terrain, and it drew on te ao Māori, both in test sites and in design concepts for the drone technology. |
| What was achieved? | Achievements include: developing AI-based models and procedures for identifying predators from thermal and other images/data; developing and testing radio data networking protocols for sensor and drone data communication; and developing robotic hardware and software modules using mātauranga Māori co-design aligning with Ngahere concepts and sustainability/ biodegradeablity.<br><br>Further, external co-funding increased research outputs.<br><br>• A substantial PF2050 contribution funded development of a volatiles sensor, 360 degree infrared-triggered tracking cameras, team support in te ao Māori, plus substantial support for field trials enabling realistic testing under typical conditions.<br>• Biological Heritage Challenge co-funding enabled development of algorithms for smart sensor deployment, and specifications for sensor swarm technology.<br><br>Assisted by engagement with stakeholders and guidance from the Advisory Group and others, Ending With Impact Booster Funding enabled assessment of specific stakeholder interests and the building of a business case to establish next steps. |
| What's next? | The project and full team will transfer to PF2050 oversight via a contract with Scion. This will allow a second field trial in June and a third planned for October 2024 to be carried out and analysed.<br><br>In addition, there are plans to shape proposals for funding agencies to resource the next phase of development, which will cover commercial prototyping, production, testing in different terrains, and interfacing with eradication activities. |

# Appendix C

## SEEDS

### Round One Seed Projects (2016)

1. A giant leap for small displacements
2. Algae-derived food supplement
3. A self-healing silicon electrode for lithium battery applications
4. Controlling spray droplets in flight: new science enhancing innovative capacity
5. Enabling sustainable economic development with advanced additive manufacturing of wood
6. Golden Polymer for Enriching Biogas to Biomethane
7. Magnetic silver clusters - a disruptive technology in bio imaging
8. Mechanically induced drug release
9. Nitrate Sensor Arrays

### Round Two Seed Projects (2017)

1. Acoustic Vector Network
2. Closing the Gaps in Static Program Analysis
3. Computational Glasses; Head mounted displays for the visually impaired
4. Data analytics to enable wide-area monitoring of electricity distribution lines
5. Deployable Nano-Satellite Synthetic Aperture Radar for Monitoring NZ's EEZ
6. Distance and Direction Estimation for Acoustic Bird Monitoring
7. Executable Heart-On-Chip for validating cardiac devices against drug effects
8. In-Vehicle Touchscreens: Improving Human Performance and Reducing Attentional Demands
9. Landscape-scale augmented reality: enhancing public understanding of our cultural heritage
10. Machine Learning Based on Rat Brains
11. Mechanochemical conversion of biomass into commodity chemicals
12. Modelling and improving emissions/energy efficiency in NZ's transport systems
13. Novel Approaches for Impaired Speech Recognition
14. Secure, shared and collaborative: treasure in the block chain
15. Underground wireless data acquisition network using Low Power Wide Area Network
16. Visual recommender technology for exploratory analytics: predicting forests futures
17. Womb with a view: Software connecting pregnant women and fetus
18. Wearable sensors for gait assessment in lower extremity disability population

## Round Three Seed Projects (2019)

1. A light in dark places
2. A new transistor exploiting electronic spin
3. A platform device for vision testing applications
4. Agent-based building earthquake evacuation simulation – AB2E2S
5. Artery heterograft development
6. Biological mimicry for medical diagnostics
7. Building a clinically validated AI classifier to assist the national Diabetic Eye Screening program
8. Bringing biochemistry to new heights – development of protein crystallisation nanosatellites
9. Consolidating Cordyline for Green Composites
10. Cellulose-based surfactants – Enhancing manufacturing and product performance with minimal environmental impact
11. Development of an innovative multidimensional manufacturing and intelligent fluid management
12. Developing real-time lab-on-chip device and biosystems for personalised cancer medicine
13. Deep sheep – facial recognition for tracking kinship in livestock
14. De novo drug discovery for type 2 diabetes mellitus treatment using deep-learned generative models
15. Environmental sensors
16. Effective telediagnostic platform with rich communicational information in the sensitive situation
17. Electricity demand flexibility on New Zealand farms
18. Hybrid organic / inorganic nanoparticles for luminescent solar concentrators
19. New approach to microwave processing for the production of bio-based chemicals
20. Portable low-cost microwave brain scanner for stroke detection and recovery monitoring
21. Self-cleaning molecular sponges for chemical sequestration
22. Towards 3D printable polymers containing biologically active antimicrobial enzymes

# Appendix D

## BOLT-ONS AND EWIPS

### Early Career Researcher Bolt-on Projects

| | |
|---|---|
| The Matariki Hunga nui project | Building a mobile phone-compatible Mixed Reality (MR) based tātai arorangi (Māori astronomy) experience with immersive content about Matariki |
| Better Diabetes care for whanau | Ensuring new insulin pumps are easy to use for everyone. |
| Robots that learn | A pipeline for early career researchers to obtain the research skills in robotics and automation that are in demand in the industry |
| Remote controlled smart sponge for precision plant care | A simple shape-shifting monitoring device with a remote-controlled sponge that can be used to manage plant care by adding or extracting water. |
| Building Rangatahi Veracity Capacity | Enabling early-career researchers to engage with the issues of veracity (trustworthiness, truthfulness and authenticity of information, data and artefacts). |

### Ending With Impact Projects (EWIPS)

| | |
|---|---|
| Translating Disruptive MedTech Across the Innovation Chasm | Developing ultra low-cost insulin pumps and sensors to provide equitable health outcomes for diabetes patients |
| Shape-shifting Meta-surface Reconfigurable Antennas for Better Wireless Communication | Developing self-tuning antennas to support telecommunications companies using 4D printing |
| Digital Twin Robotics: Industry-led Development of a Forest Surveying Robot | Developing an autonomous forest mulching robot for clearing forestry access tracks |
| Your Ātea Natural Language Processing (NLP) Platform | Developing Māori-designed and governed systems to enable whānau, hapū and iwi to interact with their data using te reo Māori |

## Ending With Impact Projects (EWIPS)

| | |
|---|---|
| Virtual Immersive Wānanga | Developing tech tools so people and groups can meet virtually and interact as if in-person |
| Ocean Intelligence | Combining customised sensors and data analytics to enable large-scale ocean farm management |
| Autonomous Underwater Vehicle for Ocean Survey | Developing adaptive data analysis software for an underwater robot that can scan aquaculture beds and give farmers high-quality images and videos |
| Te Pā Tūwatawata | Ensuring data sovereignty and the continuity of Māori data consciousness |
| Rongowai Flood Resilience Sensor Framework | Advance New Zealand's flood monitoring and response systems using next generation Global Navigation Satellite Systems Reflectometry (GNSS-R) sensors. |
| Improvement of Accessibility and Searchability of Historic Map Images | Developing interactive database of historic NZ maps for public access. |

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