Assessing the Feasibility of a Microfabrication Cluster in New Zealand

An Interactive Qualifying Project submitted to the faculty of
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Requirements for the degree of Bachelor of Science

Sponsored by:
Callaghan Innovation

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Abstract

This project assessed the feasibility of establishing a microfabrication cluster in New Zealand for Callaghan Innovation and provided them recommendations for the establishment and success of this proposed cluster. We conducted 35 interviews and found that 94% of interviewees were interested in a cluster. The perceived barriers to the formation of the cluster included: a lack of communication within the industry, internal competition, and funding. Despite these barriers we concluded that this industry cluster was feasible. We recommended that Callaghan Innovation hold central meetings where potential cluster members can discuss the cluster's operation and move forward, focusing on solving industry weaknesses, improving communication, and addressing the needs of cluster members.

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Disclaimer

This Interactive Qualifying Project was written as a requirement for the completion of a Bachelor of Science degree from Worcester Polytechnic Institute. The authors are not experts or professionals on microfabrication or industry clustering. This document was written for Callaghan Innovation. This document does not represent the opinion of Callaghan Innovation or Worcester Polytechnic Institute.

Executive Summary

In industries throughout the world, companies and institutions band together to form clusters, or groups of interconnected organizations associated with a particular field or industry. These organizations include companies and firms, specialized suppliers, associated research institutions, universities, and service providers (MassTech, 2015). An industry cluster can potentially strengthen the success of individual high-tech organizations and catalyze industry growth. Our team assessed the feasibility of establishing a microfabrication cluster in New Zealand for our sponsor Callaghan Innovation, a government organization focused on assisting New Zealand business through technology (Callaghan Innovation, 2015).

Microfabrication is the creation of devices and structures that contain features on the scale of 1 micron to 1 millimeter, as well as the processes involved in the creation of these devices and structures. People around the world use products of microfabrication, sometimes referred to as microelectromechanical systems or MEMS, in our everyday lives. MEMS devices consist of structures, actuators, electronics, or sensors inside cell phones, computers, and other devices (MEMS & Nanotechnology Exchange). Many people may not be aware of its impact, but without microfabrication, technology would not have evolved to the point that it has today.

Microfabrication has applications in many industries and a variety of settings and this is crucial for the growth of the industry in New Zealand. Many New Zealanders are involved in primary industry, including agriculture and fishing, rather than technology based fields such as microfabrication. There are many applications of microfabrication that can contribute to primary industry and the growth of the New Zealand economy as a whole. Integrating microfabricated devices into already established New Zealand industries to improve processes is an important concept for the future of all the industries involved. Some examples of these industries that have potential to be involved with microfabrication include the agricultural industry, the medical industry, and the environmental industry.

The dairy industry accounts for 39.1% of agriculture in New Zealand and farmers can apply MEMS heavily in this area (Treasury, 2012). Devices created using microfabrication can help ensure the quality of milk and overall health of the herd by detecting pathogens in milk which can indicate a diseased cow. (Smith & Gottfried, 2015). In addition, there are medical applications such as using devices for applications like monitoring blood glucose levels in real-time for diabetics (Huang, 2014). Microfabricated devices can also be a lab-on-a-chip where researchers can analyze samples in the field rather than take them to an off-site lab which could take days. The University of Cincinnati has microfabricated a disposable device for sensing heavy-metal ions in soil and water that researchers can use as a lab-on-a-chip, thus greatly increasing their efficiency (Zou, Z. et al., 2007).

The goal of this project was to assist Callaghan Innovation in assessing the feasibility of establishing a microfabrication cluster in New Zealand. The three objectives of the project were to evaluate the current state of the microfabrication industry in New Zealand and the needs of the organizations, to determine the willingness of New Zealand organizations to join a cluster initiative and to determine the potential barriers hindering the formation of the cluster, and to identify the perceptions of industry members with respect to the environmental concerns of their work and with respect to New Zealand culture as it pertains to the microfabrication industry in New Zealand.

We accomplished the goals of our project by conducting semi-structured interviews with a variety of stakeholders including researchers, manufacturers, suppliers, and students in the microfabrication field. Throughout the project, we interviewed 32 representatives from these four stakeholder groups as well as the CEO of Callaghan Innovation and two Maori: the Maori Business and Relationship Manager at Callaghan Innovation and a Principle Advisor of the Maori Economy at the Treasury Department, for a total of 35 interviews. The team conducted these interviews in Auckland, Christchurch, Wellington, and through a digital questionnaire if a face-to-face meeting wasn't possible. The digital questionnaire asked the same questions as the interviews that the team conducted and both included 26 questions inclusive to every stakeholder group and five to nine questions specific to the different stakeholder groups.

In order to prepare the information gathered from these interviews for both qualitative and quantitative data analyses, the team used a form of data processing called coding. We used a coding method that included a total of ten categories, derived from the project's goals and 46 individual codes. These codes consisted of recurring themes and ideas that the team found in the interviews. To perform the quantitative data analysis, the team tallied how many interviewees responded with each code and created tables and graphs to represent the responses from each stakeholder group. We then compared the quantitative data from the different stakeholder groups in order to identify any similarities and differences between the groups. We also generated numbers from our overall interviewee pool in order to determine the views of the industry as a whole related to our three objectives.

The team only used qualitative analysis when there were not enough interviewees who mentioned a certain topic. This occurred in only one situation where the two Maori interviewees commented on cultural attitudes toward high tech industries. In this instance, we compared the opinions from both of these interviewees and synthesized this information into general views for both interviewees.

After completing the data processing and analysis, the team generated results concerning the project's three objectives. The interview responses indicated that the major strengths of the current industry are the collaborative atmosphere within New Zealand, the variety and quality of specialists within each sector, and the mobility and adaptability of the industry and its products. The team determined the major weaknesses of the industry to be the small population size of New Zealand and scale of production, the absence of a developed industry, the competition with other countries, and the limited amount of government funding for high-tech industries including microfabrication. The interview responses also suggested that the major barriers to the microfabrication cluster formation in New Zealand are the lack of communication within and between industry sectors, funding for the cluster, and competition within sectors. As far as the perceived environmental impacts were concerned, the interviewees revealed that they believe there are some possible environmental hazards due to the chemicals used in microfabrication processes; however, some also believe that these chemicals pose little concern when properly handled. As far as the perceived societal impacts were concerned, a good number of the interview respondents believe that the social impact of microfabrication in New Zealand is very similar to the changes that occurred globally, but also believed that the public awareness of microfabricated technology is very low. The two Maori who we interviewed both explained that from their perspectives, there were not significant cultural concerns regarding microfabrication. However, this cannot represent the entire Maori population or their belief system and only represents the ideas and opinions of these two individuals who we interviewed.

Based on the data collected, the team believes that the microfabrication industry cluster initiative in New Zealand is feasible due to the pre-existing collaborative atmosphere and high percentage of interviewees (94%) who said that they are willing to join a microfabrication cluster in New Zealand. To form a successful microfabrication cluster in New Zealand, the project team generated five recommendations for Callaghan Innovation:

- In order to facilitate communication between sectors, Callaghan Innovation should hold large central meetings where all potential cluster members can openly discuss the way the cluster should run and move forward, while also helping to raise awareness of involved organizations within and between the industry sectors.
- Potential cluster members should discuss the suggestions proposed by various interviewees within the industry about how to make the cluster successful, such as the

use of a mediator, having a common vision for the cluster, obtaining funding external to the cluster, keeping the cluster applicable to the individuals' work, and representing all cluster members equally.

- The organizations interested in becoming part of this cluster should prioritize finding solutions to the main weaknesses we identified: competition, scale of production, funding, and industry visibility and existence.
- The proposed future industry cluster should exploit the advantage of having small products that can be shipped cheaply.
- The potential cluster should make efforts to make other industries and individual consumers more aware of microfabricated technology and its benefits. Integrating microfabrication into primary industries, such as agriculture or forestry, may help to create a larger domestic market for microfabrication.

We hope this project has provided valuable information for Callaghan Innovation in their efforts to assess the feasibility of a microfabrication cluster in New Zealand. We believe this cluster initiative is feasible and Callaghan Innovation can use the recommendations from this report to determine what they need to focus on in order to establish the proposed cluster.

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1 Introduction

All over the world, technological industries are developing as a result of innovative progress made in scientific fields of study. The growth of these technological industries has created a great deal of societal change, especially considering the miniaturization of technology over the last decade, and these changes continue as high-tech industries flourish. As society adapts to technology, high-tech industries need to expand to meet the demand for products. Connections formed through links between supply firms, manufacturers, research organizations, and educational facilities, also known as an industry cluster, can potentially strengthen the success of high-tech industries and catalyze industry growth.

In New Zealand, the focus is mainly on primary industries, and high-tech secondary industries such as microfabrication are not as prevalent (A., Best, personal communication, 14/1/2016). Callaghan Innovation, a government organization focusing on using technology to promote New Zealand business, wants to establish a microfabrication cluster in New Zealand thus strengthening the technological industry presence. Creating a microfabrication cluster, connected through technology and geographic nodes, has the opportunity to strengthen the industry in New Zealand.

In order to establish a microfabrication cluster, the different organizations and sectors involved must establish a community of trust, sharing, and communication. To discover which of these elements already exist, we interviewed companies, research institutions, and other related organizations within the microfabrication industry in New Zealand. If these organizations collaborate with each other, they have the potential to form a successful industry cluster in New Zealand. Figure 1.1 shows the companies and institutions that have the potential to become part of a microfabrication cluster that the team interviewed. The business culture in New Zealand has shown itself to be receptive to clusters as evidenced by successful industry clusters that currently exist, like the Marine Export Group (MAREX) boat-building cluster (Valerie, 2005).

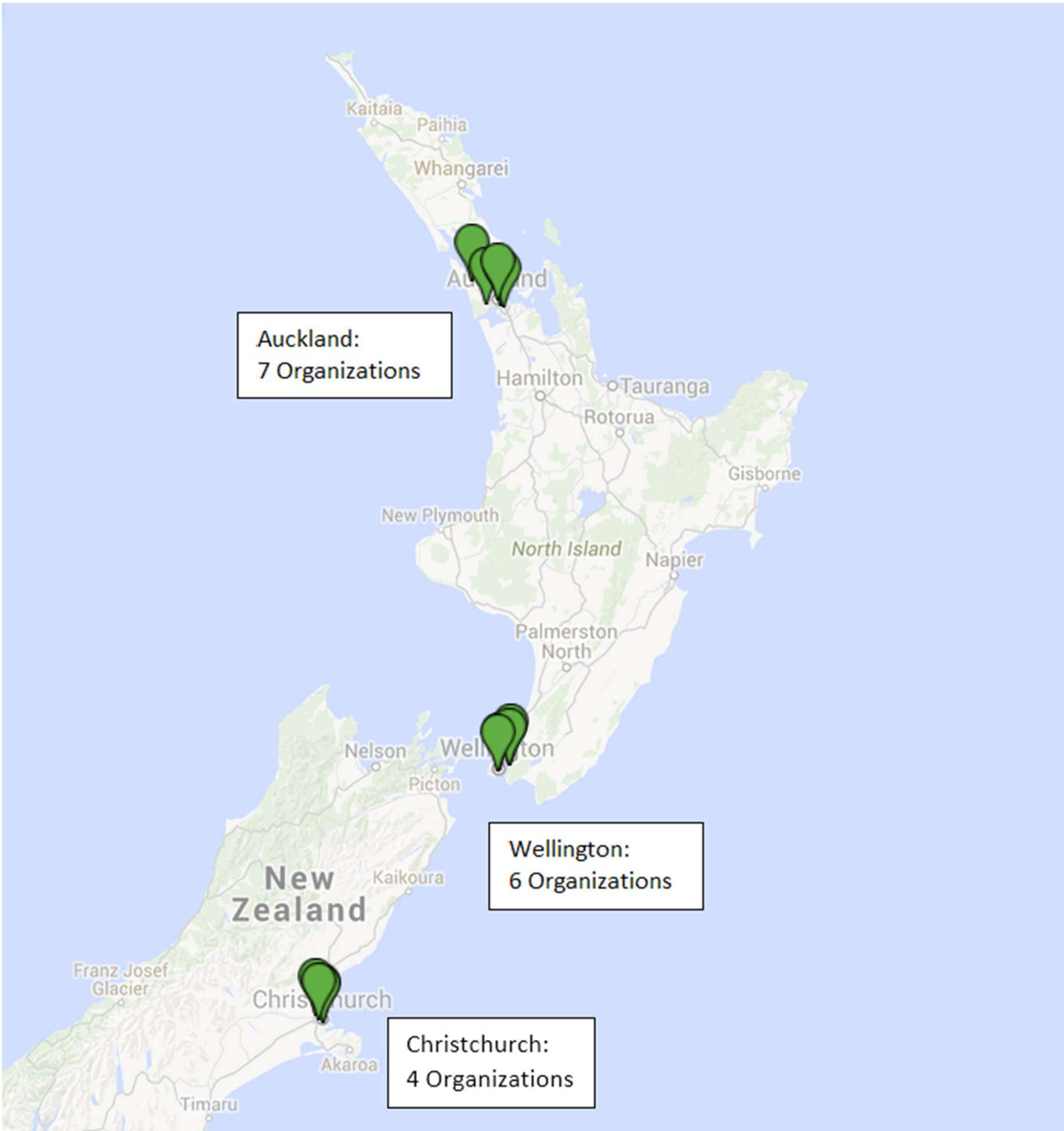

Figure 1.1: Map of Organizations

In order to facilitate the emergence of a successful microfabrication cluster, we evaluated the views and opinions of New Zealand experts in the field, as these were the people who make up and support the industry. Understanding the technical aspects of creating a cluster, as well as understanding the interviewees' perceptions of the effects such a cluster will have on New Zealand's environment and culture, was key to accomplishing the goals of this project. We achieved our three objectives by evaluating opinions and needs of the key stakeholders – suppliers, manufacturers, researchers, students, and other experts involved with microfabrication – through interviews. Some major concerns that we addressed in the interview questions were weaknesses of the industry, barriers to cluster formation, willingness of the company or institution to join a cluster, awareness of other sectors, and the perceived environmental and cultural concerns with the microfabrication industry in New Zealand.

The team coded the interview transcripts, a process that involves highlighting key points and sentences in order to quantify the raw data, to generate data for analysis. From our analysis, we found that the major strengths of the industry in New Zealand are its collaborative atmosphere and specialization. We also determined that 94% of our interviewees had some level of interest to join a microfabrication cluster initiative. Finally, the perceptions of the industry members are such that they believe that there are environmental concerns with microfabrication, but many of them believed that their organizations are handling them properly. These do not reflect the reality of the environmental impacts of microfabrication, but rather the perceptions of industry members. These current strengths and apparent willingness of organizations to join the cluster initiative are key aspects for the foundation of a successful cluster; however, the environmental concerns arising from microfabrication, if not properly dealt with, can inhibit the potential success of the cluster. Therefore, we believe that the establishment of a microfabrication cluster in New Zealand is feasible, but some organizations may need to address environmental concerns. We used these results to create recommendations for Callaghan Innovation regarding the best methods for the success of the potential microfabrication cluster in New Zealand.

2 Background

The first part of the background lays out the foundations of microfabrication in order to familiarize the reader with the field. The next section discusses the theory behind the formation and sustainment of a cluster and this section gives a brief background of an already existing cluster initiative in New Zealand and lays out the typical characteristics of currently successful clusters. The background then focuses on primary industry in New Zealand such as agriculture and explains how this industry is thriving, as well as what the microfabrication industry needs to do in order to move forward from its current state if it is to succeed. Microfabrication has applications to other existing New Zealand industries, which Section 2.5 elaborates on. The following section explains the foundation that New Zealand already has to support a microfabrication cluster initiative. Finally, the background explains some environmental hazards that the industry may produce and the government regulations that organizations in this industry must follow.

2.1 Microfabrication

Microfabrication is the creation of devices and structures that contain features on the scale of 1 micron to 1 millimeter, as well as the processes involved in the creation of these devices and structures. The products of microfabrication are sometimes referred to as microelectromechanical systems, or MEMS. These systems consist of structures, actuators, electronics, and sensors and there are a variety of applications, including chemical etching and high-aspect-ratio lithography (MEMS & Nanotechnology Exchange). High-aspect-ratio lithography is a process in which researchers shine UV light through a photoresist, a material designed to act similarly to a camera film negative, to create a pattern on a silicon wafer (MicroChem, 2015).

One overarching institute that supports the microfabrication industry in New Zealand is the MacDiarmid Institute for Advanced Materials and Nanotechnology in Wellington. This institute is a research center that works closely with suppliers, industrial companies, and other research institutions in order to make advancements in this technology (Callaghan & Blaikie, 2009). This chain of companies and institutions has the opportunity to work with other microfabrication organizations in New Zealand to form a cluster which would be beneficial for the New Zealand economy and for the future of the industry in the country. One government organization that is actively trying to develop this microfabrication cluster in New Zealand is Callaghan Innovation.

2.2 Industrial Cluster Theory

Clusters are groups of interconnected organizations associated with a particular field or industry. These organizations include companies and firms, specialized suppliers, associated research institutions, universities, and service providers (MassTech, 2015). Alongside the geographic proximity that typically characterizes clusters is the sharing of common resources. The different organizations that constitute a cluster all implicitly and explicitly share certain commonalities such as knowledge, infrastructure, growth opportunities, and barriers to growth. As one firm succeeds, another will copy them and reap the benefits. However, if one company fails, there is a strong chance that more will follow.

2.2.1 Formation and Sustainment of Hotspots

Valerie Lindsay, from the School of Marketing and International Business, in the Victoria University of Wellington, uses the Marine Export Group (MAREX), an export-based New Zealand boat building cluster, as an instructive example for exploring the formation and evolution of high-performing industries. The study she performed on MAREX suggests that the reason for the formation of industry clusters is the belief that the benefit of being in a cluster increases as more organizations enter (Valerie, 2005). There is one specific type of cluster categorized as a "hotspot." Rapid economic growth exists inside these hotspots, often with a focus on technology. The firms comprising these clusters are competitive and highly innovative with distinct identities. However, with this rapid growth of clusters comes a trend of decline in the absorptive capacity of the individual firms and of the cluster (Valerie, 2005).

The absorptive capacity of a firm is the measure by which it gathers and uses knowledge from outside the firm. It is this attribute of hotspots that ultimately leads to the failure of the cluster. Access to and application of new information fosters the innovation and adaptation potential that a firm needs to survive. In declining hotspots, there is an encompassing reduction in a firm's adaptive capacity. The adaptive capacity of a firm gauges how the firm reacts to unexpected situations and new technology, as opposed to absorptive capacity which represents how a firm gathers and uses new information. This reduced adaptive capacity results in limited new knowledge, which in turn hinders the innovative processes that sustains firms in these high-growth industries (Valerie, 2005).

In order for firms in these hotspot clusters to sustain themselves, the individual firms need to prevent themselves from falling into a competency trap. This happens when a firm tends to plateau in terms of innovation and growth. When companies rely too much on internal processes and ignore external input, the firm cannot recognize new opportunities. This contrasts with the co-evolutionary view which is using both inside and outside sources for expansion of the individual firms and the cluster as a whole (Valerie, 2005).

2.2.2 MAREX: A New Zealand Hotspot

In the late 20th century, New Zealand's boat-building industry, similar to today's microfabrication industry, was an emerging industry. As an industry, there was high demand for its products, with 50% of New Zealanders enjoying boating and 30% fishing, but the core components of a strong industry, such as business strategies and supporting industries, were lacking. Several factors that shaped the growth of the industry include an extensive coastline, favorable climate, university research, and international competition (Valerie, 2005).

The boat-building industry in New Zealand employs 8000 people in over 1300 companies. MAREX consists of about 175 of those companies, specializing in the construction of superyachts and racing yachts. As of 2005, MAREX experienced a growth of 25% per year for five years, classifying it as a hotspot. Even with the small percentage of New Zealand firms within the boat-building industry, MAREX sales account for a large portion of New Zealand's marine industry's annual sales (Valerie, 2005).

The problem with hotspots is that a trend of high growth leads to individual firms entering competency traps ultimately leading to market decline of the individual firms and the industry. MAREX avoids this problem by using both internal and external sources of information. This diversity is the reason behind the constant stream of new knowledge. MAREX includes firms who specialize in clothing, cabinet making, communication, engines, sails, and spars, in addition to the core boat-building firms (Valerie, 2005).

The microfabrication industry can learn from the MAREX cluster. For the boat-building industry, the University of Auckland has a Yacht Research Unit, and for the microfabrication industry, the MacDiarmid Institute for Advanced Materials and Nanotechnology. Similarly to the demand for boats in New Zealand, the demand for microfabrication is rising with the demand for smaller technologies in New Zealand and around the world. To help stimulate the growth of the microfabrication industry, there is also an international market within the microfabrication field.

2.3 Primary Industry in New Zealand

2.3.1 Economic Overview of New Zealand

The New Zealand economy has been through dramatic changes in the past three decades including changes in its government regulations, recent disasters including the devastating Canterbury earthquakes from 2010 to 2011 (McSeveney, 2014), and the effects of the global financial crisis in 2008. However, New Zealand has managed to maintain a steady recovery in response to its most recent struggles. The New Zealand Treasury released an economic and financial overview in 2015 discussing their recovery and their economic outlook (The Treasury, 2015).

Through reductions in government regulations, in the OECD (Organisation for Economic Co-operation and Development), New Zealand has evolved from one of the most regulated national economies to one of the least regulated countries. However, the government has put into place policies that support firms and companies and allow them to make more independent decisions about how they want to proceed. This will allow the microfabrication industry to grow and adapt to any changes more easily (The Treasury, 2015).

In response to the global financial crisis, the government tried to restore the lost confidence in the economy by helping the banking sector, individuals, and businesses. To help the banking sector, the government set in place retail and wholesale bank guarantees. They also incorporated cuts in the income tax as well as relief packages for small and medium-sized companies to assist individuals and businesses. The Canterbury earthquakes of February 2011 slowed this recovery. However, the recovery is acting as a source of growth through residential, commercial, and infrastructure investments.

2.3.2 Manufacturing in New Zealand’s Economy

A major problem facing the manufacturing sector in New Zealand is the exchange rate of the New Zealand dollar. The IMF (International Monetary Fund) suggested in 2012 that the New Zealand dollar was 10-20 percent overvalued (Wheeler, 2013). Governor Graeme Wheeler stated in a speech addressing the New Zealand Manufacturers and Exporters Association in Auckland that along with the issue of overvaluing the New Zealand dollar, there were other components such as globalization, outsourcing, international supply chains, and the competition between low cost producers that were hurting the state of New Zealand industries like microfabrication (Wheeler, 2013).

The lack of skilled labor and the current architecture of the manufacturing sector makes the creation of a sustainable microfabrication cluster in New Zealand difficult. In order to shed light on the situation, Castalia, an advising company, created a report for BusinessNZ on the dynamics and competitiveness of New Zealand and its manufacturing sector (Castalia, 2014). In their report, Castalia conducted a study involving 15 New Zealand manufacturing companies showing high growth to ascertain the factors determining strong growth in the future. A couple of the main issues that Castalia highlights in this study are the architecture of the industry and the shortage in skilled labor.

2.3.3 Manufacturing Sector Architecture

The focus of the manufacturing industry in New Zealand has shifted from manufacturing to a mix of manufacturing and services including research, design, and marketing. This shift has caused some misunderstandings about the sector’s composition and, consequently, its strategies for sustainable growth. Using official government statistics, Castalia concluded that there were misconceptions on the classification of specific units (Castalia, 2014). In particular, many products and services that New Zealanders classify as in the services sector are in fact a part of a vertically integrated business in the manufacturing sector. In other words, the firms that are manufacturing these services are also the ones who distribute the services. Instead of having a separate company handle the service, the firm handles it internally. This adds to the labor shortage problem due to added confusion about the role of manufacturing in New Zealand. Castalia determined that the common factors that make firms in a cluster successful are talent-driven innovation instead of a cost-minimization approach and a vertically-integrated architecture. The success of these individual firms then in turn would make a successful and competitive manufacturing sector in New Zealand.

2.3.4 Primary Industry Sectors

Primary industry in New Zealand consists of agriculture, fishing, and forestry. This is most likely due to New Zealand's geographic factors. New Zealand is an island nation, making fishing a highly accessible industry, and has 14.3 million hectares designated as farming land (Beef+lamb New Zealand, 2015). The labor force is abundant in these booming industries because generations of New Zealanders integrated farming, gardening, and forestry into their lifestyles. These areas account for about 16% of the nation's labor force. In 2012, there were 60,562 farmers and farm managers in New Zealand compared to 5,388 Information and Communications Technology (ICT) professionals and this disparity was even worse in 2002 (Grimmond, 2014). The agricultural industry is directly responsible for 5.0% of GDP (Treasury, 2012) and approximately 50% of total income from exports comes from meat, dairy, and wool products (Productsfromnz.com, 2015). In New Zealand, 44% of farms are "mainly sheep and beef farming" and another 21% are "mainly dairy farming" (Beef+lamb New Zealand, 2015) making sheep and cattle the most relevant elements of the agriculture industry in the country. As a whole, New Zealand is highly agriculturally and environmentally focused and less targeted toward high-tech fields such as microfabrication.

2.3.5 Skilled Labor Supply

The lack of skilled labor in the manufacturing sector is a problem hiding in the shadows of the economic success of the industry in New Zealand, but it will become more of an issue the longer companies and institutions ignore it (Castalia, 2014). Castalia stated that the manufacturing industry provided 191,000 jobs by the middle of 2013 and was supplying 14.6% of the country's GDP in 2012. This makes it one of the four largest sources of jobs and income in New Zealand, establishing New Zealand as more manufacturing-heavy than its neighbor, Australia. However, the survey conducted by Castalia targeting high-growth manufacturing firms determined that the lack of skilled labor is the highest concern in the industry (Castalia, 2014). Culturally, this is an issue, as many citizens do not view themselves as a nation that relies on manufacturing. This may lead to many people not choosing a manufacturing career path, thus contributing to the lack of skilled labor.

2.4 Microfabrication Applications in other New Zealand Industries

It is important for the microfabrication industry in New Zealand to make connections with already established industries in the country in order to grow and expand. Many New Zealanders have been involved in primary industry, including agriculture and fishing, rather than technology based fields such as microfabrication. What these primary industry workers may not know however, is that there are many applications of microfabrication that can contribute to primary industry and the growth of the New Zealand economy as a whole. Integrating microfabricated devices into already established New Zealand industries to improve processes is an important concept for the future of all of the involved industries. Some examples of these industries include the agricultural industry, the medical industry, and the environmental industry.

2.4.1 Agricultural Applications

As previously mentioned, agriculture is one of the largest industries in New Zealand. Consequently, for the microfabrication industry in New Zealand to be successful, it must make efforts to connect these two industries.

The dairy industry accounts for 39.1% of agriculture in New Zealand and farmers can apply MEMS heavily in this area (Treasury, 2012). One such application is a device, seen in Figure 2.1 that can detect and immobilize pathogens including E.coli, Streptococcus, and Staphylococcus in milk in real time (Smith & Gottfried, 2015). This is incredibly useful, not only to ensure the quality of milk, but also because it can lead to early detection of diseases such as mastitis in dairy cows. Mastitis is an inflammation in mammary tissue and is a financial issue in dairy industries worldwide, costing the U.S. one billion dollars annually (Smith & Gottfried, 2015).

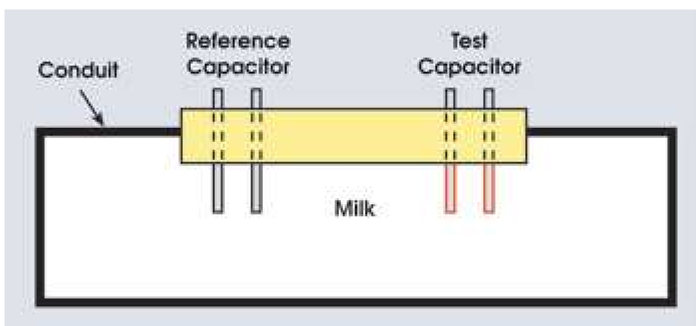

Figure 2.1: Sensor in milk conduit (Smith, 2012)

Additionally, SpectralSight Inc. developed a microfabricated device that is applicable in the agricultural industry. This device utilizes hyper-spectral imaging to detect problems in crops and food. By tuning the device to specific light frequencies, users can detect fungal infections and needs for irrigation (Smith & Gottfried, 2015). Users can also utilize this type of device for food that is already packaged and on store shelves (Smith & Gottfried, 2015). Detecting these issues increases both production and quality of the food.

2.4.2 Medical Applications

There are numerous areas that microfabrication technology applies to the medical field, one of which being biosensors. Two specific biosensors that could be important to New Zealand healthcare are continuous glucose monitoring sensors (Huang, 2014) and heart-failure-monitoring sensors (Sjm.com, 2015).

Diabetes is the fastest growing health problem in New Zealand with over 240,000 people diagnosed with the disease (Ministry of Health NZ, 2015). Glucose-monitoring sensors are the main tool diabetics employ to keep track of and control their blood sugar. The Department of Mechanical Engineering at Columbia University has developed a fully implantable MEMS dielectric affinity glucose biosensor. This biosensor monitors blood glucose concentrations in real time so that the user doesn't have to take blood samples throughout the day (Huang, 2014).

Heart disease is the leading cause of death in New Zealand, resulting in 30% of deaths annually (Heartfoundation.org.nz, 2015). Devices applicable to this area of the medical field are helpful to the general health of New Zealand. St. Jude Medical, in Tennessee, has developed the CardioMEMS™ HF System which is a tool for early detection of heart failure. The device monitors the pulmonary artery pressure with an implanted sensor. This device, as seen in Figure 2.2, has reduced heart-failure-related hospitalizations by 43% in clinical trials throughout the US (Sjm.com, 2015).

Figure 2.2: Heart Failure Monitor System (CardioMEMS HF, 2015)

Another medical application of microfabrication is in research. Technicians currently use micropatterning methods, a form of microfabrication, to fabricate the extracellular environment for cancer cells to grow in (Yang et al., 2015). This aids in arrangement, proliferation, and cell behavior research which is important to understanding how cancers form and respond in the body (Yang et al., 2015).

2.4.3 Environmental Protection Applications

While environmental protection is not a typical industry, it does have many microfabrication applications and is fundamentally important as it deals with the safety of the environment. There are several sources citing the potential use of micro-sensors to monitor environmental conditions to detect pollutants (Suzuki, 2000) (Zou, Z. et al., 2007) (Feeney & Kounaves, 2000). The environmental protection industry can reduce manufacturing costs by switching over to microfabricated devices instead of using their macro counterparts. This is due to batch fabrication, which allows lab personnel to make more sensors at once, and multi-analyte detection which means that one device can detect and analyze several different molecules or pollutants (Feeney, 2000).

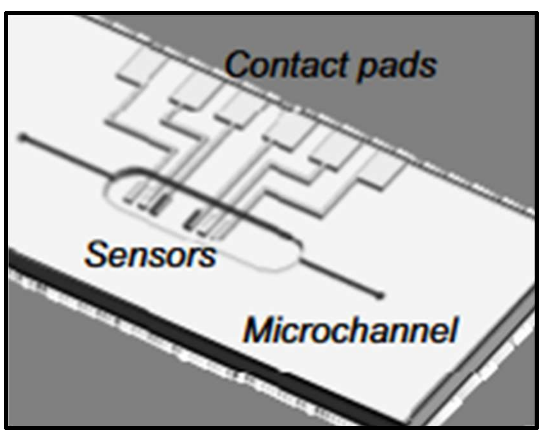

Figure 2.3: Heavy-metal ion sensor (Bishop, 2007)

The University of Cincinnati has microfabricated a disposable heavy-metal ion sensor as seen in Figure 2.3. Researchers can use this sensor at the site they are analyzing (Zou, Z. et al.,

2007) meaning they do not need to take samples off-site to a lab. This is not only more convenient, but also much more efficient. The device is able to accurately detect harmful materials such as lead ions in the soil and in water sources without producing toxic chemicals in the process (Zou, Z. et al., 2007). This is important because the ultimate goal of using these sensors is to decrease the amounts of pollutants in the environment.

2.5 Existing Foundations for a Microfabrication Cluster in New Zealand

The MacDiarmid Institute for Advanced Materials and Nanotechnology is a partnership between several main research institutes for microfabrication in New Zealand; it is a public institute surrounded by branching institutions and companies known as Crown Entities. There are seven current entities, consisting of five universities and two Crown Research Institutes, in which the MacDiarmid Institute oversees microfabrication research. This institute propelled the research on microfluidics and nanotechnology so that other companies such as Callaghan Innovation could carry on with specific research to fulfill a desired purpose (Yewdall, 2015).

2.5.1 Crown Entities of the MacDiarmid Institute

Callaghan Innovation works together with organizations affiliated with the MacDiarmid Institute on nanotechnology research as well as industrial applications of this research. The University of Auckland and the University of Canterbury are crucial contributors to this effort as well. The latter played a role in the creation and commercialization of self-assembling nanowires, working heavily with the MacDiarmid Institute (Callaghan & Blaikie, 2009).

Callaghan Innovation is a technology oriented company which pledges to take the ideas of researchers and commercialize them. This is one of the most prominent New Zealand companies containing researchers in the field of microfabrication. These researchers have made great progress in recent years in trying to improve the microfabrication industry in New Zealand; Callaghan Innovation is currently at the forefront of the industry in this country (Callaghan & Blaikie, 2009).

An article in the journal Smart Materials and Structures contains a step-by-step process in which Andrea Bubendorfer and two other researchers from Callaghan Innovation used microfluidic devices to fabricate microchannels and seal them to a substrate. Demonstrating the ability to produce microstructures and make use of them is the first step for companies trying to break into the microfabrication industry. The second step is figuring out how to lower the cost of production and manage changing technologies, something Callaghan Innovation is focusing on now (Bubendorfer, 2007).

Another Crown Entity that works closely with the MacDiarmid Institute is the University of Auckland. It has an entire facility dedicated to research on microfabrication for both academia and industry. The students at the University of Auckland Microfabrication Facility complete projects dealing with single cell microfluidics, drug delivery and biosensing actuators, gas sensors, and sensors for sound waves. These projects are important because they allow University of Auckland students to become proficient in a variety of microfabrication processes and this prepares them to begin working in the microfabrication industry once they've finished university. In fact, microfabrication consulting is an integral part of the academia-industry relationship that the University of Auckland tries to keep intact (University of Auckland).

This research is not simply for the university itself, however. It is also helpful for the growing microfabrication industry in New Zealand. For example, companies in this industry have already used the University of Auckland's facilities "to improve processing conditions for biomedical and industrial polymers, for the design of flowcells for dairy waste stream sensors, and to explore new concepts in gas sensor design" (University of Auckland). The University of Auckland Microfabrication Facility and similar facilities will be important as the microfabrication industry in New Zealand grows because they are institutions crucial for researching efficiency and conditions for various microfabrication processes and products.

2.5.2 MacDiarmid Institute Strategic Plan

Not only is the MacDiarmid Institute making technological progress, it is striding towards social and cultural progress in terms of increasing public acceptance of technical industries. One way it is accomplishing this feat is by conducting social research with the general public about their opinions on nanotechnology and related fields. This research found "that the New Zealand public generally views nanotechnology favourably, but that there is some aversion to products where people can be directly exposed to nanoparticles" (Callaghan & Blaikie, 2009). If the institute knows that the public is averse to certain technologies, it can determine whether these technologies are actually a concern, make efforts to mitigate these concerns if necessary, and ultimately increase public acceptance of the industry.

In the next six years, the MacDiarmid Institute expects to make significant progress in three areas: increasing the potential for technological advancement and human capital, positively influencing New Zealand's economy, and generating changes in social attitudes that increase favorability of microfabrication and the desire to explore a career in such a field (Yewdall, 2015). One of the techniques to inspire change in New Zealand society is interacting with specific groups of people who may not be initially interested in microfabrication. The MacDiarmid Institute has identified these groups of people as the Maori and Pasifika, and a crucial part of the aforementioned six-year plan deals with attempting to integrate these groups into the industry. The plan is to "Develop, grow and formalise relationships with Māori communities founded on mutual exploration of education and business opportunities supported by a science foundation" (Yewdall, 2015: 4). The institute recognizes that some Maori are not necessarily going to be interested in the microfabrication industry due to their culture; however, Yewdall believes it is essential that the institute educates the Maori and Pasifika about career opportunities and reasons why the microfabrication industry is beneficial. To achieve this, the MacDiarmid Institute will introduce scientific development programs in predominantly Māori and Pasifika schools (Yewdall, 2015).

2.5.3 University of Auckland

Figure 2.4: University of Auckland (Grafton Campus, 2008)

Young innovators collaborating with the MacDiarmid Institute and related organizations in the microfabrication field could be beneficial to the industry. One way to facilitate young innovation would be to promote enrollment in microfabrication programs in universities such as the University of Auckland, shown in Figure 2.4. This university is the largest educational institution in New Zealand that deals with microfabrication, consisting of 41,953 total students (University of Auckland, 2014). It is the largest and highest-ranked university in New Zealand, rated as 82nd in the world according to Quacquarelli Symonds (QS) World University Rankings (University of Auckland, 2014). Proof of this university's importance also comes in the form of its research prowess. "The University of Auckland is New Zealand's largest research organisation with more than 13,000 staff and postgraduate students involved in fundamental and applied research. It generates around $230 million in annual research revenue" (University of Auckland, 2014). This university has the potential to supply the industry with new graduates who may have a fresh perspective on microfabrication.

2.6 Environmental Concerns

The microfabrication industry, like many high-tech industries, uses chemicals that have the potential to be harmful. Some New Zealanders may not support the industry if these processes have harmful environmental effects. In a country with high environmental standards, this has the potential of hindering the cluster's success.

2.6.1 Environmental Hazards of Microfabrication Industry

One of the most harmful practices related to this industry is etching. During etching, a technician develops and installs a photoresist on a wafer. This wafer's silicon dioxide layer is then stripped using a chemical solution, but the photoresist remains on the wafer. Etching is important because it is the best technique for securing a photoresist to a wafer to perform a desired function. There are two types of etching: wet etching and dry etching. Wet etching uses chemicals such as hydrofluoric acid, sulfuric acid, nitric acid, and hydrogen peroxide to strip the silicon dioxide layer off the wafer at room temperature or warmer environments. Researchers developed dry etching in order to strip certain layers that wet etching cannot handle. There are even more chemicals used in dry etching, such as chlorine, hydrogen bromide, fluorocarbons, and fluorine (Manufacture of Semiconductors, Pages 30-31).

All of these chemicals have the potential to harm the environment if not properly handled. The United States Environmental Protection Agency drafted a report about the semiconductor industry which explains, *[These] physical and chemical processing steps occur at four process operation areas … A variety of pollutants may be emitted at these stations. These include acid fumes and organic solvent emissions from cleaning, rinsing, resist drying, developing, and resist stripping; hydrogen chloride emissions from etching; and other various emissions from spent etching solutions … In addition to process related emissions, air emissions may also result from onsite treatment of industrial wastewater (Manufacture of Semiconductors, Pages 35-36).*

In the semiconductor portion of the industry especially, companies must consider the effects of the many different pollutants produced.

2.6.2 Progress on Reducing Pollutants

Many people recognize that unregulated microfabrication processes can be harmful to the environment, so the United States put into place procedures to reduce hazardous air pollutants (HAP). Between 1987 and 1994, technological advances reduced HAP releases per area of silicon substrate from nearly 0.08 to 0.01 pounds per square inch. This is a significant improvement, which is exactly what the Semiconductor Industry Association (SIA) hoped to achieve for the industry. A study by the SIA found that "HAP usage in the semiconductor industry is declining due to regulatory, worker safety, and cost pressures, and the trend is likely to continue. Many HAP materials used in semiconductor manufacture have been replaced by HAP-free materials" (Manufacture of Semiconductors, Pages 37-38). If the microfabrication industry continues to grow in New Zealand and becomes as widespread as it is in the United States, the New Zealand Environmental Protection Authority can put regulations in place to lower HAP levels.

2.7 New Zealand Legislation

There are several potential barriers to the formation of a microfabrication cluster in New Zealand regarding the government regulations associated with microfabrication. Some issues that companies and institutions have to worry about when creating devices and running processes are laws related to environment, health, and safety. These regulations are the reason that these microfabrication facilities have a safe environment in which to thrive and expand.

2.7.1 Environmental Act 1986

In 1986, New Zealand Government passed the Environmental Act which called for the Commissioner to hold in high regard “any land, water, sites, fishing grounds, or physical or cultural resources, or interests associated with such areas” (Environment Act 1986, 2014). Therefore, the New Zealand Government must monitor all areas that facilities could harm by pollution or chemical waste. This consists of investigating organizations in order to limit practices that “result in or increase pollution; or result in the occurrence, or increase the chances of occurrence, of natural hazards or hazardous substances” (Environment Act 1986, 2014).

2.7.2 Health and Safety in Employment Act 1992

The New Zealand Government enacted the Health and Safety in Employment Act in 1992 to limit workplace hazards and incidents. These limitations ensure that workers in microfabrication and related fields in New Zealand act safely and responsibly. Regarding workplace regulations, this act specifies “where there is a significant hazard to employees at work, the employer shall take all practicable steps to eliminate it” (Health and Safety in Employment Act 1992, 2013). This means that the employer is responsible for the health and safety of the employees. It is important to have these regulations in place because otherwise a facility dealing with microfabrication or other dangerous technical processes would become a hazardous workplace. If a facility becomes too dangerous, the New Zealand Government can close it, having a negative impact on a potential cluster.

2.7.3 Hazardous Substances and New Organisms Act 1996

Another potential problem confronting a microfabrication cluster in New Zealand is the Hazardous Substances and New Organisms Act enacted in 1996. While this act does protect the environment, it also greatly reduces the variety of substances and organisms that organizations can import into New Zealand, as well as the number of exported materials. The act states, “No—(a) hazardous substance shall be imported, or manufactured: (b) new organism shall be imported, developed, field tested, or released—otherwise than in accordance with an approval issued under this Act” (Hazardous Substances and New Organisms Act 1996, 2015). If regulations allowed organizations to import, export, or create whatever they wanted, then hazardous substances might become more widespread. This would hurt the industry because an increase in dangerous chemicals or organisms is bound to increase the amount of hazards and incidents involving these substances. Microfabrication companies and institutions must keep this set of regulations in mind when considering expansion and collaboration with other organizations. Throughout this project, the team gathered information about what other factors are important when organizations attempt to come together to form a cluster.

3 Methods

This project assisted Callaghan Innovation in assessing the feasibility of establishing a microfabrication cluster in New Zealand. The team accomplished this by conducting interviews with a variety of stakeholders in the microfabrication industry. The stakeholders consisted of individuals from organizations from the supply, research, manufacturing, and education sectors within the microfabrication industry in New Zealand. We used coding to process the data gathered from the interviews and then analyzed the coded data between the stakeholders quantitatively and qualitatively. The project's objectives were:

1. To evaluate the current state of the microfabrication industry in New Zealand and the needs of the organizations.
2. To determine the willingness of New Zealand organizations to join a cluster initiative and to determine the potential barriers hindering the formation of the cluster.
3. To identify the perceptions of industry members concerning potential environmental and cultural impacts the microfabrication industry may have in New Zealand.

3.1 Interview Process

The team chose to use semi-structured interviews as the sole method to achieve our project's three objectives. A semi-structured interview, also called an open-ended interview, allows the interviewer to remain flexible and responsive to the answers of the interviewee and add additional relevant questions to the conversation (Hamill, 2014). We chose the semi-structured interview type because of its flexible nature. Since our project involves interviews with interviewees with varying degrees of technical and managerial background, we made adjustments in phrasing and probing questions on the fly when needed. A completely structured interview would not have allowed our team to adjust to each interviewee in the same way as the semi-structured interview.

3.1.1 Interview Strategy

In order to collect all of the necessary information for each of the project's three objectives, the team conducted semi-structured interviews in three major areas in New Zealand: Wellington, Auckland, and Christchurch. The team's base of operations was in Wellington, and this is where we held most of the interviews. The team flew out to both Auckland and Christchurch to hold the interviews in those locations. If the location of the interviewee was in any other city, or if the interviewee was too busy to schedule a face-to-face interview but still wanted to participate in the project, we sent him/her a digital questionnaire. This digital questionnaire contained the same questions, presented in the same manner as the face-to-face interviews, designed to get the same responses as we would in a face-to-face interview. After the team distributed the digital questionnaire, we gave the option of having a phone call to answer any follow-up questions that the respondent had.

For each of the different stakeholders, the team asked the interviewees different types of questions after asking a set of general questions which applied to all the stakeholders. The different stakeholder groups that we focused on were: suppliers, manufacturers, researchers, and students. Table 3.1 shows the list of all interviews that we held, along with the company that the representative belonged to, the location of the interview, as well as a date and time stamp when the interview took place. The table is organized chronologically.

Key:	Research	Manufacturing	Supplier	Student	Other

Name	Organization	Location	Role	Date/ Time
Andrew Best	Callaghan Innovation	Wellington	Research	1/14/16 14:30
Mike Arnold	Callaghan Innovation	Wellington	Research	1/14/16 15:30
Richard Templar	Callaghan Innovation	Wellington	Research	1/18/16 10:00
Andrew Dawson	Callaghan Innovation	Wellington	Supplier	1/18/16 12:00
Paul Mather	Callaghan Innovation	Wellington	Manufacturing	1/18/16 13:30
Frederic LeCarpentier	Spark Transducers	Wellington	Research	1/18/16 15:00
Hamish McGowan	Callaghan Innovation	Wellington	Research	1/19/16 12:00
Jerome Levener	GNS	Wellington	Research	1/19/16 14:30
Leo Browning	Victoria University	Wellington	Student	1/20/16 11:30
Anonymous A	Victoria University	Wellington	Research	1/20/16 12:00
Anonymous B	Victoria University	Wellington	Research	1/20/16 12:00
Gideon Gouws	Victoria University	Wellington	Research	1/20/16 14:30
Brendan O'Connell	Tru-Test Ltd.	Digital	Research	1/20/16 16:30
Eva Weatherall	Victoria University	Wellington	Student	1/21/16 10:30

Atawhai Tibble	Ministry of Finance	Wellington	Other	1/22/16 11:00
Vincent Campbell	Callaghan Innovation	Wellington	Other	1/22/16 11:30
John Newton	Pure Depth	Auckland	Research	1/26/16 10:00
Iain Hosie	Revolution Fibres	Auckland	Manufacturing	1/26/16 10:30
Bryon Wright	MacDiarmid Institute	Digital	Research	1/26/16 13:30
Benjamin O'Brien	Stretchsense	Auckland	Manufacturing	1/26/16 14:30
Cather Simpson	Photon Factory	Auckland	Manufacturing	1/26/16 15:00
Michael McILroy	Rakon Limited	Auckland	Research	1/27/16 10:00
David Grant	Rakon Limited	Auckland	Manufacturing	1/27/16 10:00
Alan Coulson	Callaghan Innovation	Wellington	Research	1/28/16 9:30
Anonymous F	Spark Transducers	Digital	Research	1/29/16 12:00
Mary Quin	Callaghan Innovation	Wellington	Other	1/29/16 14:00
Bart Ludbrook	MacDiarmid Institute	Digital	Research	2/1/16 11:00
Anonymous C	Shamrock Industries	Christchurch	Supplier	2/3/16 11:30
Volker Nock	University of Canterbury	Christchurch	Research	2/3/16 15:00
Anonymous G	Not Disclosed	Christchurch	Manufacturer	2/3/16 13:00
Maan Alkaisi	University of Canterbury	Christchurch	Research	2/4/16 11:00

Paul Garrett	Photoetch Industries Limited	Christchurch	Manufacturer	2/4/16 13:00
Anonymous D	Victoria University of Wellington	Digital	Student	2/11/16 17:00
Anonymous E	MacDiarmid Institute	Digital	Student	2/12/16 16:00
Helen Morris	Victoria University of Wellington	Digital	Student	2/12/16 17:00

Table 3.1: Interviews Held

We used three methods to procure interviews. Our first set of interviews were with industry representatives contacted by our sponsor liaison Andrea Bubendorfer, at Callaghan Innovation. She set up the interviews directly with no involvement from the team. We conducted most of these interviews during the first week of the project. The second method we used to procure interviews was through connections from Callaghan Innovation. The sponsor shared with the team a Google Sheet consisting of different organizations involved within the microfabrication industry, representatives from those organizations, and contact information for the representatives. The team contacted each of the representatives primarily through email. If no email was available, we contacted the representatives by phone. This method provided the most interview opportunities. The third and final method we used to set up interviews was through connections disclosed by previous interviewees. These interviews contributed the least to the total number of interviews and they were set up in the same manner as the ones set up with the second method. A list of organizations that we could not interview is in Appendix C. We could not interview these organizations, either because they did not respond to our interview requests or because we did not have time to interview them; however, these organizations could still be part of a potential cluster for microfabrication in New Zealand.

Throughout the project, we used two different team configurations to conduct interviews. For the first few interviews in the beginning of the project, all four members participated. In this configuration, there was one interviewer, one backup interviewer, and two note-takers. The purpose of these interviews was to practice our interviewing skills and learn the strengths and weaknesses of each team member. We conducted the majority of the remaining interviews in groups of two, which consisted of one interviewer and one note-taker.

The interviewer was in charge of asking all questions during the interviews, including probing questions based on the responses from the interviewees. The note-taker's primary function was to audio record the interviews, with a secondary function of taking notes. We only used these notes as a backup if the audio recording was incomprehensible, or if the interviewee wished for the team to not record the interview.

3.1.2 Interview Questions

Throughout the first week of the project, the team edited and revised the questions used during the interviews for each stakeholder. Bubendorfer reviewed our initial set of questions and made suggestions on how to change them to better procure the information we needed from each stakeholder. After making these adjustments, the team conducted two practice interviews with Mike Arnold and Andrew Best, whose transcripts, as well as all other transcripts, are in Appendix D. With the comments and suggestions from Bubendorfer, who sat in on the previously mentioned interviews of Arnold and Best, we rephrased unclear or over-generalized questions, omitted redundant questions, and added missing questions that the team felt were necessary. These questions are in Appendix A.

Introduction and Confidentiality Prompt

There were three goals of the introduction and confidentiality prompt. The first goal was to introduce the team as third year engineering students from the United States studying at Worcester Polytechnic Institute in Massachusetts. The second goal was to formally introduce the project to the interviewee. The third goal was to inform the interviewee that they had the option to stay anonymous and that they had the choice to withhold any information that they provided during their interview. The prompt is as follows:

"Hello, we are third year engineering students from the US studying at Worcester Polytechnic Institute in Massachusetts. We are carrying out this project assessing the feasibility of creating a microfabrication (by which we mean miniaturized structures or devices with features that may be smaller than a millimeter) cluster in New Zealand as part of our degree program. We will be using this interview in a report that will be published and made available in the public domain. You can remain anonymous and please tell us at the end if there is any information that you do not want published. We hope our report will also be of interest to you."

General Questions for all stakeholders

1. May we audio record this interview?
2. What is your name?
3. What is the name of your organization?
4. Would you like to remain anonymous?
5. Which part of the microfabrication industry are you personally involved in? (Please select the part you are involved in the strongest.)
    a) Supplier
    b) Manufacturing
    c) Research
    d) Student
6. What part of the microfabrication industry is your organization involved in?
    a) Supplier
    b) Manufacturing
    c) Research
    d) Student

7. What is your job title?
8. What is your job description?
9. What does the word microfabrication mean to you?
10. How does microfabrication play a role in your organization?
11. How has miniaturization changed technology in New Zealand?
12. What do you imagine microfabrication in New Zealand to be like in 5-10 years?
13. How do you see ongoing miniaturization affecting the future in 5-10 years?
14. How do you think miniaturized technology impacts society in New Zealand?
15. What are the strengths of the microfabrication industry in New Zealand?
16. What are the weaknesses of the microfabrication industry in New Zealand?
17. How do you feel about collaboration with other organizations?
18. What do you know about industry clusters and how do you see a cluster operating?
19. `How aware are you of the microfabrication facilities in New Zealand?
20. How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication field? Why or why not?
21. Are there any environmental concerns with microfabrication and if so, what are they and how are they dealt with?
22. What types of government regulations affect your work?

<u>Questions 1 and 4:</u> Since we published this report in the public domain, we needed to give the interviewees the options of not being audio recorded and to remain anonymous so that they could feel free to speak openly.

<u>Questions 2 and 3:</u> These questions were purely for the audio recording so that when a team member listened to the recording it would be clear which interviewee they were transcribing.

Questions 5 and 6: The team asked these questions to identify what type of stakeholder the interviewee and their organization represented and to gain a better understanding of the interviewee's background and helped the team look for potential bias We also used question 5 to determine which set of specialized stakeholder questions we would ask the interviewee.

Questions 7 and 8: The answers to these questions provide more information about the interviewee’s personal role in their organization and how involved they are with microfabrication.

Questions 9 and 10: The team asked these questions to gauge how much understanding of microfabrication the interviewee had because not all of the people interviewed had the same familiarity or background in the field. Knowing their level of familiarity allowed us to adjust our phrasing and probing questions throughout the interview. The team also used these questions to gauge the importance of microfabrication to the interviewee and their organization. These questions addressed objective 1.

Questions 11, 12, and 13: These questions provided an understanding of how the interviewee sees the microfabrication industry currently, as well as what the interviewee expects or desires for the microfabrication industry moving forward into the future. This was important because if an individual does not have a positive outlook about the current or future microfabrication industry, then they are less likely to have a vested interest in the cluster. These questions addressed objective 1.

Question 14: The team used this question to evaluate the perceptions of the interviewees in regard to the impact microfabrication/miniaturized technology has had on New Zealand and how it has affected New Zealand society. This question addressed objective 3.

Question 15 and 16: These questions helped to identify the current assets and the disadvantages of the current microfabrication industry that could aid or hinder cluster formation and success. These questions addressed objective 1.

Questions 17, 18, 19, and 20: The team asked these questions to assess the general knowledge of the interviewee about clusters, their awareness of other related organizations, and their willingness to join a cluster. These questions addressed objective 2.

Question 21: This question revealed the interviewee's thoughts about environmental hazards caused by microfabrication processes and how they believed their organizations handled the potential hazards. This question addressed objective 3.

Question 22: The team asked this question to discover if there were any potential government regulations that affect the current and future microfabrication industry in New Zealand. This question addressed objective 1.

Supplier Questions

23. How do international trends shape the future of New Zealand microfabrication?
24. Is your company looking to hire more staff?
25. What products do your company provide for the microfabrication industry?
26. What country do you do the most business with?
27. What factors make it difficult to compete in a global market?
28. What companies do you supply in New Zealand?

Questions 23, 26, and 27: These questions gauged the scope of importance of international markets, how they affect the interviewee's organization, and how they play a role in the microfabrication industry in New Zealand. These questions addressed objective 1.

Question 24: This question gauged the growth of supplier organizations and provided the team with information about how fast the supply sector is growing in New Zealand. This question addressed objective 1.

Questions 25 and 28: The team asked these questions to gauge the range and type of business in the microfabrication industry where supplies interact with other organizations. These questions addressed objective 1.

Manufacturing Questions

29. What are the main applications of your work?
30. What is your current approach to stay relevant in this rapidly expanding field?

31. How much money does your organization spend yearly on Research and Development?
32. How much money does your organization spend yearly on microfabrication in particular?
33. How many people does your organization have on staff?
34. How many people does your organization have on staff for microfabrication in particular?
35. Is your company looking to hire more staff?
36. How do international trends shape the future of New Zealand microfabrication?
37. What factors make it difficult to compete in a global market?

Question 29: This question provided information about which fields the microfabrication industry is currently affecting, as well as the different applications that New Zealand manufacturers are providing, to gain an understanding of the progress individuals are making in this field and the applications that could contribute to the knowledge pool for a cluster. This question addressed objective 1.

Question 30: This question determined the different methods that representatives in the manufacturing sector in New Zealand are using to stay relevant. Staying relevant in the microfabrication industry is very important to the formation of a cluster as the cluster itself would have to remain relevant on an international scale. This question addressed objective 1.

Questions 31 and 32: Originally, these questions were meant to gauge the role that microfabrication plays in the individual organizations within the manufacturing sector in New Zealand to help the team determine the organizations' priorities. However, the team decided that these questions did not provide the information we were looking for and the data obtained by these questions was never used.

Questions 33, 34, and 35: These questions gauged the growth of manufacturing organizations in the microfabrication field and provided the team with information about how the manufacturing sector is growing, if at all, in New Zealand. These questions addressed objective 1.

Questions 36 and 37: The team asked these questions to determine the impact of foreign markets on the microfabrication industry in New Zealand, as well as to gauge the importance and difficulty of entering the international market for the purpose of bettering the industry. These questions addressed objective 1.

Research Questions

38. What is your current approach to stay relevant in this rapidly expanding field?
39. Is your organization looking to hire more staff?
40. What factors make it difficult to compete in a global market?
41. What are the main and potential applications of your work?
42. How much money does your organization spend yearly on Research and Development?
43. How much money does your organization spend yearly on microfabrication in particular?
44. How many people does your organization have on staff?
45. How many people does your organization have on staff for microfabrication in particular?

Question 38: This question determined the different methods that representatives in the research sector in New Zealand are using to stay relevant. Staying relevant in the microfabrication industry is very important to the formation of a cluster as the cluster itself would have to remain relevant on an international scale. This question addressed objective 1.

Questions 39, 44, and 45: These questions gauged the growth of research organizations in the microfabrication field and provided the team with information about how the research sector is growing, if at all, in New Zealand. These questions addressed objective 1.

Question 40: This question gauged the importance and difficulty of entering the international market for the purpose of bettering the industry. This question also gave the team information about the different factors that make it difficult, and provided insight into why these factors hurt the industry, and a potential cluster, on a global scale. This question addressed objective 1.

Question 41: This question provided information about which fields the microfabrication industry is currently researching, as well as the different applications that New Zealand researchers are providing. This question addressed objective 1.

Questions 42 and 43: Originally, these questions were meant to gauge the role that microfabrication plays in the individual organizations within the researching sector in New Zealand to help the team determine the organizations' priorities. However, the team decided that these questions did not provide the information we were looking for and the data obtained by these questions was never used.

Student Questions

46. Are you doing any research in microfabrication? If so, what are the applications of your research?
47. What degree(s) are you pursuing?
48. Are you looking to get a job in New Zealand or somewhere else?
49. If you are looking to get a job in another country, why?
50. If you are looking to get a job in New Zealand, why?

Question 46: The team asked this question to determine the level of involvement with microfabrication of the interviewee, as well as the specific applications that could add to the knowledge pool of a potential cluster. This question addressed objective 1.

Question 47: This question provided the team with information about what degrees students are pursuing, their relation to microfabrication, and their current research interests. This question addressed objective 1.

Questions 48, 49, and 50: The team asked these questions to ascertain the places where students are looking to get jobs, providing the team with a sense of how willing students are to stay in New Zealand, and the reasons why or why not. These questions addressed objective 1.

Concluding Questions

51. If you consider yourself Maori, do you see any major cultural conflicts with microfabrication/high-tech fields?

52. Do you have any additional comments?
53. Do you know of other companies or research groups in New Zealand that have interest in microfabrication? Who can we contact and what are your connections with these people?
54. Is there any information that you provided that you do not want published?

Question 51: The team targeted this question to the interviewees who were Maori in order to determine their perceptions on whether or not Maori had any cultural concerns with practices in the microfabrication industry in New Zealand. This question addressed objective 3.

Questions 52, 53, and 54: The team asked these questions to all interviewees at the end of the interviews to gather additional information from the interviewees via one broad, open question and allow them to strike anything they said off the record. These questions also allowed us to use snowballing techniques to obtain more contacts and interviews.

3.1.3 Trip to Auckland

For the team's trip to Auckland, due to limited time between interviews and great distances between interview locations, the team split into two separate groups: Group A and Group B, to tackle the interviews in the most efficient manner possible. In each group there was one interviewer and one notetaker. There was a total of six face-to-face interviews. Figure 3.1, displayed below, shows the locations of these interviews. To determine which group would conduct which interviews, the team took into consideration distance between locations to reduce the cost of the taxi rides between interviews and the time of the interviews to make sure that the travel was as efficient possible.

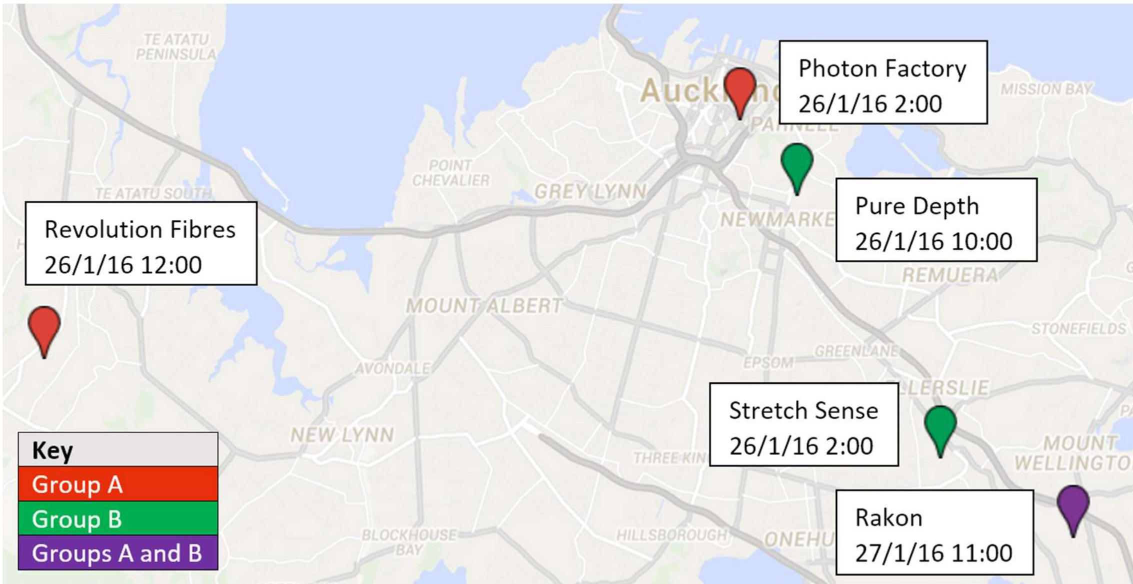

Figure 3.1: Interview Map of Auckland

3.1.4 Trip to Christchurch

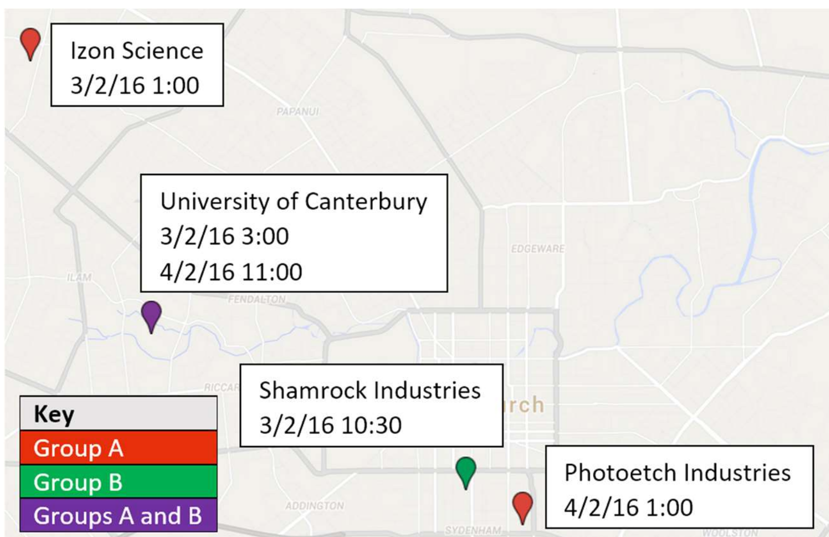

Figure 3.2: Interview Map of Christchurch

The trip to Christchurch was similar to the Auckland trip in that there was limited time between interviews and great distances between interview locations. Hence, the team again split into two separate groups: Group A and Group B, to maximize efficiency in conducting the interviews. There was a total of five face-to-face interviews. Figure 3.2 shows the locations of these interviews. To determine which group would conduct which interviews, the team again took into consideration distance between locations and the interview times in order to maximize efficiency of travel.

3.2 Data Processing

In order to analyze the information gathered from the interviews, we first needed to transcribe the interviews. The team details this process in section 3.2.1. Transcribing was a crucial step to data processing because it provided us with all the information in each interview, clearly written out. This allowed us to easily code the data later, as well as equipped us with the ability to quote something directly from an interview into our final report. The team decided upon coding versus another data processing method due to its properties as a heuristic, "an exploratory problem-solving technique without specific formulas or algorithms to follow," in linking together the data collected to the idea (Saldaña, 2012). The team decided to use the grounded theory method to prepare the textual data from the interviews with all stakeholder groups for a quantitative analysis. The grounded theory allows for hypothesis-generating research, as opposed to hypothesis-testing research. Hypothesis-generating research allows research to begin without a hypothesis to test. It allows for the generation of the hypothesis or hypotheses after the collection of the data (Auerbach & Silverstein, 2003). This was crucial to our project, as we did not know what the outcomes of the interviews would be until we had actually conducted the interviews.

3.2.1 Transcribing

Interviewee: Iain Hosie
Interviewer: Rachel Ooyama-Searls
Organization: Revolution Fibres Ltd
Location: Auckland
Date and Time: 26/1/2016 12:00:00

Rachel: For our records can you please state your name?
Iain: Iain Hosie.
R: And the name of your organization?
I: Revolution Fibres Limited. I'm the managing director.
R: Which part of the microfabrication industry are you personally involved in: supplier, manufacturer, research or student?
I: We are manufacturers and research as well so we run essentially manufacture of nanofiber but more often than not there's a huge amount of product development that has to go on before the manufacture and so we offer that as a customization service as well. So it's paid research and we're sort of recognized in New Zealand as advanced materials specialists. Our speciality is nanofiber but we have quite a broad understanding of all chemistries.
R: What part of the microfabrication industry is your organization involved in? Again the same four options. Manufacturing and research?
I: Yes.
R: Can you state your job title?
I: Managing Director and Founder.
R: In your own words can you give us a job description?

Figure 3.3: Sample of Transcribed Interview

We began the transcribing process by uploading our recordings to our computers. At the start of the process, all four group members listened separately to recordings, typing out the recordings word for word into a Google Document. Each team member used a slightly different software to playback the audio recordings. Some software was able to filter out some of the background noise which made it easier to hear the interviewee. Other software slowed down the audio recording to provide a more continuous approach to transcribing without the need to pause frequently. Both of these methods sped up the transcription process, allowing the team to transcribe more interviews in a shorter period of time. Further along in the project, the team realized that the transcription process was taking a long time, and that the coding process would also be very time-consuming. Consequently, we divided into two teams: one team of the fastest transcribers to finish transcribing the interviews and one team to start the coding process of the already transcribed interviews. Figure 3.3 shows a sample of a transcription and the completed transcripts are in Appendix D.

3.2.2 Bias Study

Before the team could start the coding process, a bias study needed to be held to ascertain any potential biases between the different team members. Due to the splitting off into two separate teams for transcribing and coding, only two members initially performed the study. The study consisted of two separate parts: the individual coding of the same transcript and the discussion of any differences in the results. The team drew two conclusions from this bias study:

1. There was a difference between the two team members in how they highlighted certain sections of the transcript. There were times when both members used different codes, classifying the highlighted section in different objectives. With this bias toward certain codes and objectives, the team decided to discuss each code and decide on a single meaning. The team wrote down these meanings so that for future coding, it would be clear to the coder what each code meant. As another result of these differences, the team decided to have the ability to assign multiple codes to the same idea. This means that if one section of a transcript fits more than one code, given the updated meanings, the coder could assign all applicable codes to the section of the transcript.
2. The second conclusion that the team drew from the bias study was about the differences between the words society and culture. The team nullified this confusion by combining the two previously separate categories: “New Zealand Culture” and “New Zealand Society” into “New Zealand Culture and Society.”

After the team identified these differences, we adjusted and defined the coding process through discussion of the codes and decided how we would code moving forward with the project. After the first two team members completed the short study, the other two members repeated the same process with the same transcript. With similar discussions, all four of the team members were arriving at same results. With this study finished, all four members of the team could start coding the transcripts individually and with minimized bias.

3.2.3 Coding

Codifying is “a process that permits data to be ‘segregated, grouped, regrouped, and relinked in order to consolidate meaning and explanation’” (Saldaña, 2012). The team decided to use a four-layered approach to coding: objectives, categories, codes, and subcodes. The broadest layer of this approach were the objectives, which were our project's three objectives. These objectives lay out what we aimed to achieve through the project, so they were a good starting point for determining our codes. We then separated the project's three main objectives and narrowed them down into different categories. For example, our objective pertaining to the perceived environmental and cultural concerns with the microfabrication industry split into two categories: one for the perceived environmental concerns and one for cultural concerns. The team broke the first objective into five different categories, the second objective into three, and the third into two, for a total of ten categories. We further divided each category into smaller codes that applied to the responses that the interviewees gave. Within the ten categories, there were 46 different codes pertaining to various concepts relevant to the project.

The first step in the coding process for any given transcript was to highlight the different sections of the transcripts that applied to a specific code using the color scheme that the team determined prior to coding. Throughout the process, there were two predominant methods for highlighting the transcripts. The team used the first method early in the coding process, before knowing the individual codes well. This method required the coder to pick one category, read the entire transcript, and highlight any portion where the interviewee mentioned the topic of the code. After the team became familiar with the codes, we used the second method. This method was to read through the transcript one sentence at a time, deciding which code was most relevant for each portion of the transcript. This allowed the coder to code each transcript more efficiently.

Due to the large number of codes used in the coding process that we agreed upon, we could not assign every code a unique color. To address this problem, we made sure that every code in the first two objectives, for which there were enough colors, had a unique color. For the third objective, the team used repeat colors if needed. While highlighting, the coder would mark those sections that required codes from the project's third objective with the letter E in parentheses: (E). The "E" is shorthand for Environment, which is a large part of the project's third objective. To address the existence of subcodes, the highlighted portion included a number signifying which number subcode the highlighted portion fell under in parenthesis. Additionally, for the category "Current and Future Outlook," the highlighted portion included a "C" or an "F" placed before it in order to specify "current" or "future" respectively. This was to identify whether the idea was referring to the future or present times. For our coding purposes, the team had a Google Document that identified each of the colors as well as the numbers for each of the subcodes. Appendix B has all of the information on the colors chosen for the codes and the numbers used for each of the subcodes.

Due to the nature of our coding methodology, if there was a portion of the interview that did not satisfy any current codes, the coder would discuss with the team if there should be a code and, if it was deemed necessary, add it to the list of codes. Due to the communication between coders and the discussion of any possible new codes, there was little chance that any newly added code had already appeared in previous transcripts. This cut away the need for a second complete cycle of coding transcripts, something the team initially planned on doing. However, after discussing the new code in question, if it was deemed necessary, the team would indeed continue on to perform a second cycle of coding. This second cycle would only focus on the new code or codes, and would use the coded transcripts from the first cycle. For the subcodes, as they are more specific answers to the general ideas represented by the codes, the team decided that a discussion was not necessary beyond the relevancy of the new subcode, as the exclusion of a specific subcode would not change the highlighting of previous transcripts. This is due to the fact that the coders were looking for the codes and not the subcodes during the highlighting process. The section "Organization of Codes" below represents the different codes. Detailed below are the objectives, categories, codes, and subcodes. The codes and subcodes are also found in Appendix B. Below in Figure 3.4 is a sample of a coded transcript.

R: How do you see ongoing miniaturization affecting the future in 5-10 years? Or do you?

L: So(F7) I think miniaturization is going to be less of an issue. We're getting towards as small as we can get, realistically. At least, in the areas that we are working on. So I mentioned that a little earlier. So I think working at a lower scale is going to be still extremely valid but just purely making what we got smaller is perhaps not the best way of looking at things.

R: How do you think miniaturized technology has impacted society in New Zealand?

L: So this is once again probably just a global answer and New Zealand is a reflection of that. But I mean,(C7) miniaturization of technology has improved accessibility because often with miniaturization it's all about process optimization. So when you optimize a process you either get faster, cheaper, smaller, or better. Sometimes a combination of the two. (C7) it has made technology more accessible and it's made it more prevalent.

R: In your opinion what are the strengths of the microfabrication industry in New Zealand?

L: The strengths, okay, the collaborative atmosphere. I'm going to speak purely about the research side of things. There is manufacturing and this touches on the collaborative atmosphere as well. So in the research section, we often work closely with the manufacturing sector often for some equipment and expertise they have on processes and they work with us for research essentially, for investigative work and sometimes equipment that we have that they don't. (2) Why I think the collaborative environment is so important is that there is a lot of big companies around the globe, big countries, big research economies, and there is no reason why a small country, small economy, small research group can't contribute but it needs to be in a collaborative way in order to kind of best engage on a global scale, compete.

R: Next question. What are the weaknesses of the microfabrication industry here in New Zealand?

L: Scale. Size. Right. So the issue is size and mostly that comes down to equipment, right.

Figure 3.4: Sample of Coded Transcript

<u>Organization of codes</u>

<u>Objective 1</u>

To evaluate the current state of the microfabrication industry in New Zealand and the needs of the organizations.

1. Current and Future Outlook
    a. <u>Technology and Applications</u>: The team designed this code to group information on the current and future technologies created with the use of microfabrication. The team split this code into seven subcodes: “Sensors,” “Actuators,” “Textiles,”

"Lab on a chip," "Electrical," "Other," and "Impact or effect of microfabrication." The team used the first six subcodes to differentiate how different industries use microfabrication within New Zealand. The subcodes "Biomedical," "Communication," "Environment," "Primary industries", and "Other" represent these industries. The team created the last subcode to differentiate between specific applications of microfabrication and specific information about how microfabrication has impacted technology in New Zealand. The sub-subcodes for this last subcode are "Global interaction," "Business," "No effect," and "Disruptive vs. incremental".

b. International Influences: This code grouped information on the influences of other countries on the technology in New Zealand.

c. Efficiency: This code grouped information about the increased efficiency of devices as a result of microfabrication in different fields, or the potential increase.

d. International: The team designed this code to group information about the current and future international involvement and effect on the microfabrication industry in New Zealand. The team split this code into five subcodes: "Trends," "Markets," "Difficulty," "Collaborating internationally," and "Influences of technology".

e. Awareness of Personal Involvement: This code grouped information related to how aware the interviewee is of their company's involvement within the microfabrication industry in New Zealand. The team split this code into five subcodes: "Unaware that they do microfabrication," "Aware that they do some microfabrication," "Only does microfabrication," "Does not do microfabrication," and "Indirectly involved with microfabrication."

f. Industry Future: The team designed this code to group information on the outlook of the future of the microfabrication industry from the eyes of stakeholders. The team split this code into seven subcodes: “Uncertain,” “Positive outlook,” “More collaboration,” "Move away from primary industry," "Incorporate into primary industry," "Increase in manufacturing abilities," and “Negative outlook”.

2. Strengths
   a. Specialists/Specialization: The team grouped responses talking about the specialists that work in the microfabrication industry in New Zealand.
   b. Mobility/Adaptability: The team grouped information about the mobility and adaptability of the microfabrication industry in New Zealand, meaning ease of transportation, ease of shipping, and flexibility in terms of switching research industry focus to better align with local and global markets. The team broke this code into three subcodes: “Shipping,” “Schedules,” and “Flexibility.”
   c. Facilities: The team grouped responses citing the different microfabrication facilities in New Zealand as a strength of the industry.
   d. Research Sector: The team grouped responses citing the research sector and research facilities in New Zealand as a strength of the microfabrication industry.
   e. Innovation: The team grouped responses citing the level of innovation present within the microfabrication industry in New Zealand as a strength of the industry.
   f. Improvisation: The team grouped responses pertaining to the ability of New Zealanders to improvise solutions with limited resources.
   g. None: The team grouped responses indicating that there were no real strengths in the microfabrication industry in New Zealand.
   h. Communication / Proximity: The team grouped responses about the ability to communicate, through a phone call or otherwise, with other national or international industry representatives.

i. Collaborative Atmosphere: The team grouped responses about the collaborative atmosphere in New Zealand between stakeholder groups or within a stakeholder group, including responses mentioning current clusters in New Zealand that add to the collaboration.

3. Weaknesses:

   a. Government Regulations: The team grouped responses citing government regulations that might inhibit the formation of the microfabrication cluster in New Zealand due to the extra efforts needed to comply. The team split this code into three subcodes to differentiate the regulations each stakeholder identified: "Health and safety," "Customs/Importing and exporting," and "Environment."

   b. Size/Scale: The team grouped responses citing New Zealand's population size or production quantity as a hindrance to the microfabrication industry in the country. The team split this code into two subcodes: "Size of country" and "Scale of production."

   c. Funding: The team grouped responses citing that the levels of funding within their company or within the microfabrication industry in New Zealand are too low. To differentiate between lack of government funding, lack of internal funding, and competition for funding with other industries, the team split this code into three subcodes: "In general," "Due to government," and "Competition for funding."

   d. Facilities/Equipment: The team grouped responses saying that the microfabrication facilities and the equipment in those facilities in New Zealand are not as good as they are in other countries, or subpar.

   e. Industry Existence/Visibility: The team grouped responses addressing the visibility of the microfabrication industry in New Zealand from the eyes of the general public and from other industry representatives, as well as the lack of key sectors, such as suppliers or manufacturers. The team split this code into four subcodes: “Lack of complete industry,” “Public visibility,” “Underestimated/Not taken seriously,” and “Global visibility.”

f. Lack of Communication: The team grouped responses stating that there is a lack of communication in the microfabrication industry in New Zealand and the rest of the world. The team split this code into three subcodes: “Between sectors,” “Within sector,” and “With the rest of the world.”

g. Global Competition: The team grouped responses addressing the difficulty of competing with other companies and organizations, as well as what countries the competition comes from. The team split this code into two subcodes: “Against China” and “Against other countries.”

h. Need for Immediate Globalization/No Market in New Zealand: The team grouped responses talking about the lack of a market for microfabrication in New Zealand, and the need for immediate globalization.

i. Distance: The team grouped responses citing the distances between the different microfabrication facilities and the distances from other countries as a weakness of the microfabrication industry in New Zealand. The team split this code into two subcodes: “Between New Zealand facilities,” and “From other countries.”

j. Lack of People: The team grouped responses stating that the lack of people, including production staff and principal researchers, is a weakness in the microfabrication industry in New Zealand. The team split this code into two subcodes: “Skilled labor,” and “Specialists.”

k. Lack of Supply/Resources: The team grouped responses about the lack of suppliers and resources in the microfabrication industry.

4. Education:

    a. Degrees: The team grouped responses pertaining to what degrees students are pursuing. The team split this code into five subcodes: “Electrical Engineering,” “Mechanical Engineering,” “Physics,” “Chemistry,” and “Other/Not specified.” The team used the “Other/Not specified” subcode only in the one digital questionnaire, where we were unable to clarify the student's degree in person.

    b. Jobs in New Zealand: The team grouped responses about students wanting to stay in New Zealand for their career in microfabrication. The team split this code into four subcodes: “Family/Significant other,” “Home,” “The environment,” and “Culture.”

    c. Jobs outside of New Zealand: The team grouped responses about students wanting to leave New Zealand in search for a career in microfabrication. The team split this code into six subcodes in order to determine their reasons for wanting to leave: “No jobs,” Poor facilities,” “Not competitive globally,” “From a different country,” “Family/Significant other,” and “Desire to travel.”

Objective 2

To determine the willingness of New Zealand organizations to join a cluster initiative and to determine the potential barriers hindering the formation of the cluster.

1. Willingness:

    a. Conditions to Join: The team grouped responses about the idea that something else needs to be present before the representative would join a cluster initiative for microfabrication in New Zealand. The team split this code into four subcodes based on what the interviewees wanted to see in a cluster initiative: “Mediator,” “Common goal,” “External funding,” “All parties equally represented,” “Applicable to Personal Work.”

b. Not Interested: The team grouped responses about the idea that there is no interest for some industry representatives in joining a cluster initiative in microfabrication. The team split this code into two subcodes based on the interviewees' reasons for not wanting to join a cluster: “Academia” and “Think it cannot work.”

c. Interested: The team grouped responses about why industry representatives might be interested in joining a cluster initiative for microfabrication. The team split this code into seven subcodes to gauge the scale of interest and skepticism about the cluster: “Benefits to organization,” “Benefits to New Zealand,” “Benefits to all organizations,” “Skeptical of success,” “Decreases national competition,” “Personal gain separate from organizational gain,” and “Trading staff.”

2. Barriers:

a. Funding for Cluster: The team grouped responses citing the lack of funding for the sustainment of the microfabrication cluster as a barrier to the formation of the cluster.

b. Common Vision: The team grouped responses about the existence of a common vision for the cluster. When this common vision is lacking, it is a barrier to the formation of a microfabrication cluster in New Zealand. The team split this code into two subcodes: “Between sectors” and “For the cluster as a whole.”

c. Internal Competition: The team grouped responses relating to the idea of competition between other organizations or other countries being a barrier to the formation of a microfabrication cluster in New Zealand.

d. Relevancy Methods: The team grouped responses about the various methods that the industry representatives use to stay relevant with current processes and technologies. The team split this code into six subcodes: “Reports,” “Academic journals," "Conferences," "Trading Staff," "Not enough time to stay up to date," and "Clusters/Relationships with other organizations."

e. Lack of Communication: The team grouped responses about the various relationships, within sectors or between sectors, which are not present in the microfabrication industry, acting as a barrier to the formation of the cluster. The team split this code into two subcodes: "Between sectors" and "Within sectors."

f. Awareness of Industry: The team grouped responses about the individual's awareness of other organizations within the microfabrication industry in New Zealand. The team split this code into three subcodes: "Very aware," "Partially aware," and "Not aware." The team then split each of these subcodes into three additional sub-subcodes to identify which connections between sectors are not present: "Research/Universities," "Manufacturers," and "Suppliers."

g. Growth of Company: The team grouped responses about the growth of the companies of the interviewees based on whether the company had hired more staff recently, or if they will be hiring in the future. The team split this code into three subcodes: "Staying the same," "Growing," and "Declining."

3. Knowledge of Clusters:

   a. Knowledge of Clusters: The team grouped responses to ascertain the level of knowledge of clusters among industry representatives. The team split this code into four subcodes: "Current clusters," "Clusters they are/have been involved in," "Little to no knowledge," and "Familiar with just the concept."

Objective 3

To identify the perceptions of industry members concerning potential environmental and cultural impacts that the microfabrication industry may have in New Zealand.

1. Environmental Concerns:
    a. Concerns to Environment: The team grouped responses pertaining to the various perceived environmental concerns facing the microfabrication industry in the form of chemicals, solvents, or nanotechnology. The team split this code into six subcodes: “Heavy metals,” “Nanotechnology,” “Solvents,” “Chemicals,” “Other,” and “Hazardous waste handled properly.”
    b. No Concerns to Environment**:** The team grouped responses saying that there were no perceived concerns to the wellbeing of the environment. The team split this code into three subcodes: “Too small a scale to produce harm,” “Chemicals properly handled,” and “Nothing harmful is produced at all.”
2. New Zealand Culture and Society:
    a. Maori: The team grouped responses concerning the perceived impact of microfabrication on Maori culture. The team split this code, used primarily for the two Maori interviews, into nine subcodes: “Ability to adapt,” “Open to technology,” “Conservative Views,” “Economic Growth,” “Primary Industry,” “Education/ Involvement,” “Cultural conflicts,” “Exposure to S.T.E.M.,” and “Clusters.”
    b. Open to the Idea of Clusters: The team grouped responses about the openness and awareness of New Zealand culture to the idea of clusters.
    c. Openness to and Awareness of Technology and Microfabrication: The team grouped responses about the usage of high-tech devices in New Zealand, as well as the awareness of the usage of high-tech devices. The team split this code into two subcodes: “Openness” and “Awareness.”
    d. Primary Industries: The team grouped responses about the different primary industries and their importance in the New Zealand society.

e. Ease of Life: The team grouped responses about the increase to the ease of life in New Zealand that microfabrication brings, such as through the impact of devices like cell phones.

f. Change Similar to Global Change: The team grouped responses about the idea that microfabrication has impacted New Zealand society in the same way that it has affected the rest of the world.

3.3 Data Analysis

The data analysis procedure consisted of three steps: analyzing the demographical data acquired from the interviews, quantitatively comparing the similarities and differences between stakeholder groups by objective, and qualitatively analyzing the data pertaining to the perceived Maori cultural concerns. Section 3.3.1 details the demographical analysis that the team used and section 3.3.2 details the quantitative and qualitative analyses by objective. The team used the combination of these analysis steps and the conclusions drawn from them to create our final recommendations for the establishment of a microfabrication cluster in New Zealand.

3.3.1 Demographical Data Analysis

The team created pie charts to represent the demographic data that we collected from our interviews. The demographic data included how many interviewees and organizations the team interviewed from each of the stakeholder groups. In addition to the key stakeholder groups of researchers, manufacturers, suppliers, and students, the team included an “other experts” classification to include all other interviewees that did not associate with any of the key stakeholder groups.

3.3.2 Analyses by Objective

For the quantitative analysis, the team picked out key, countable categories related to our objectives that were prevalent in all of the interviews and tallied the number of interviewees that responded with ideas that we were able to code using specific codes within the categories in order to display them graphically. Once the team finished going through all the transcripts, we counted the tallies within a stakeholder group and compared those tallies in the tables which are located in Chapter 4. This allowed the team to draw conclusions concerning the relationship between each stakeholder group and the project's three objectives. Where appropriate, the team also created graphs to display the views and opinions of the entire interviewee pool. Analysis of these graphs led to conclusions about the microfabrication industry as a whole. Each table or graph is accompanied by an analysis about the importance of the similarities and differences to the formation of a potential microfabrication cluster in New Zealand.

For the qualitative analysis, the team analyzed the responses from the two different Maori interviewees. To do this, we coded their transcripts and compared the similarities and differences in their statements. This gave us some ideas about their opinions, but didn't necessarily allow us to make decisive statements about their responses due to the small sample size.

Based on the mixture of quantitative and qualitative data analysis, the team was able to draw conclusions about how the views of the different interviewees and stakeholders influenced the cluster initiative. These conclusions helped the team determine the feasibility of establishing a microfabrication cluster in New Zealand and resulted in the creation of final recommendations about how to establish a microfabrication cluster.

4 Results and Analysis

As a note to the reader, this chapter uses the generic terms: researcher, manufacturer, student, or supplier to specifically refer to the individuals that we interviewed who are working in those sectors within, or relating to, the microfabrication industry in New Zealand. The team also interviewed three other experts who did not identify with any of the four major stakeholder groups. These interviews were with the CEO of Callaghan Innovation and two Maori: the Maori Business and Relationship Manager at Callaghan Innovation and a Principle Advisor of the Maori Economy at the Treasury Department. We incorporated the data collected from these individuals in the combined analysis of the data where applicable. The team drew these results specifically from the interviewed population and we cannot generalize these results with confidence to the whole microfabrication industry or the specific sectors of the microfabrication industry in New Zealand.

4.1 Demographical Data Analysis

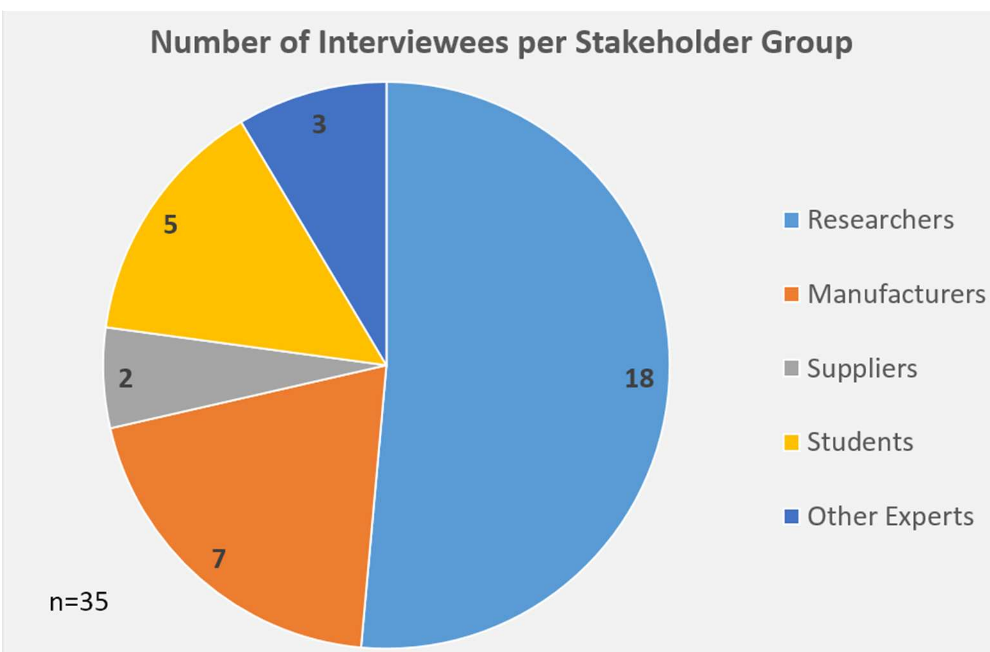

Figure 4.1: Number of Interviewees per Stakeholder Group

Figure 4.1 displays the number of interviewees who identified themselves in one specific stakeholder group. The majority of the interviews we conducted were with researchers. The possibility that researchers were more willing to talk about the potential for a cluster initiative can explain the difference in the number of interviews conducted, but it is more likely to be the result of the dominant number of researchers within the current microfabrication industry in New Zealand. The fact that researchers make up more than half of our interviewees may indicate that the research sector for microfabrication in New Zealand is more prevalent than the other sectors of the microfabrication industry in New Zealand. The team struggled to find suppliers to interview and as a result only interviewed two. This may possibly indicate a lack of actual suppliers of microfabrication products in New Zealand.

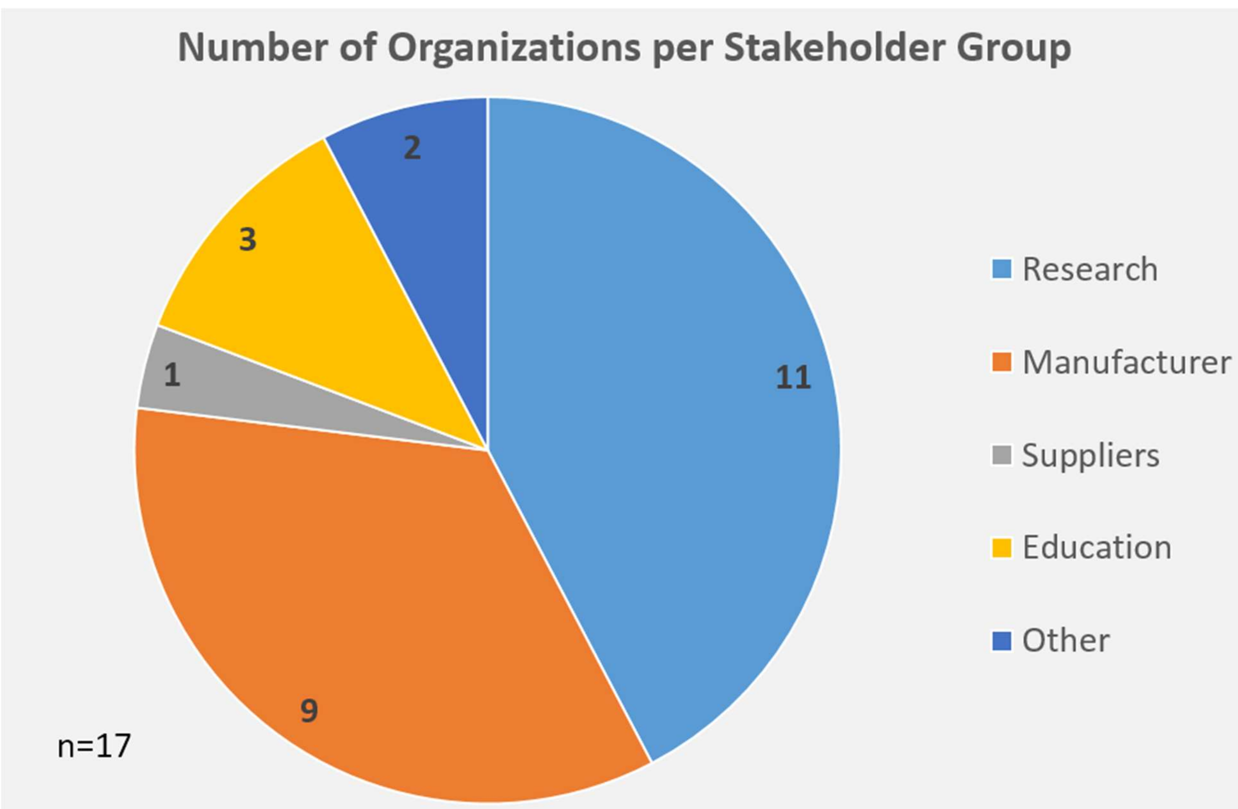

Figure 4.2: Number of Organizations per Stakeholder Group

Figure 4.2 displays the number of organizations per specific stakeholder group based on the responses from the interviewees. We asked each interviewee to also categorize their organization into a sector or sectors of the industry (research, manufacturing, supplier, and education). The organization the interviewee belonged to could be different from the interviewee's personal involvement. Some interviewees identified their organization as being in multiple sectors, which accounts for the fact that there were 17 organizations, but there are 26 responses in the pie chart.

4.2 Objective 1

The project's first objective was to evaluate the current state of the microfabrication industry in New Zealand and the needs of the organizations. From the semi-structured interviews the team conducted with members from each of the stakeholder groups, the team identified five key themes to concisely represent the data that we collected that is germane to our first objective. These are: "Strengths of the Microfabrication Industry in New Zealand," "Weaknesses of the Microfabrication Industry in New Zealand," "Efficiency," "Future Outlook of the Microfabrication Industry in New Zealand," "Plans after Graduation." Sections 4.2.1 to 4.2.5 display the data that the team gathered from the interviews and the analysis of this data.

4.2.1 Strengths of the Microfabrication Industry in New Zealand

The team evaluated the perceived strengths of the current microfabrication industry in New Zealand based on responses to Question 15: **"What are the strengths of the microfabrication industry in New Zealand?"** and represented the responses in Table 4.1 and Figure 4.3. It is important to note that the team did not specifically prompt for any of the specific strengths of the industry and that we based all specific strengths on the interviewees' responses. It is also important to note that interviewees were able to give as many or as few strengths as they wished in the interviews and the total count of strengths does not necessarily match the number of interviewees.

Strengths Mentioned	**Researcher**		**Manufacturer**		**Student**		**Supplier**		**Other**		**Total**	
Specialists	7	39%	4	57%	0	0%	0	0%	0	0%	11	31%
Mobility	4	22%	3	43%	0	0%	2	100%	0	0%	9	26%
Facilities	1	6%	0	0%	1	20%	1	50%	0	0%	3	9%
Research Sector	1	6%	3	43%	1	20%	2	100%	0	0%	7	20%
Innovation	0	0%	2	29%	0	0%	1	50%	1	33%	4	11%
Improvisation	3	17%	3	43%	0	0%	0	0%	0	0%	6	17%
Communication / Proximity	1	6%	0	0%	0	0%	0	0%	0	0%	1	3%
Collaborative Atmosphere	6	33%	3	43%	1	20%	2	100%	0	0%	12	34%
None	2	11%	0	0%	0	0%	0	0%	0	0%	2	6%
Number of Responses	18		7		5		2		3		35	

Table 4.1: Interviewee Identified Strengths of the Microfabrication Industry in New Zealand

Table 4.1 shows that 39% of researchers said that specialists and specialization in the microfabrication industry in New Zealand are a strength whereas 57% of manufacturers said the same and no students or suppliers identified it as a strength. This data may suggest that manufacturers consider specialists and specialization to be more important to the success of the microfabrication industry in New Zealand or that they are more aware of the specialists compared to the other three stakeholders groups. Table 4.1 also reveals that only 1 out of 18 researchers and 1 out of 5 students, two groups mainly involved with research, identified the research sector as a strength of the microfabrication industry in New Zealand. However, the data for manufacturers and suppliers shows that 43% of manufacturers and 100% of suppliers identified the researching sector to be a strength. This suggests that the stakeholder groups who are not directly and wholly involved with research believe that the researching sector is important whereas the individuals working directly in research may undervalue their role.

Knowing the current strengths of the microfabrication industry is important because these strengths will help form the foundation of the potential microfabrication cluster in New Zealand. Knowing the strengths is also important as these strengths help the industry recognize which areas do not need as much attention. Essentially, knowing the strengths helps to prioritize where energy and resources should go when trying to improve the industry as a whole.

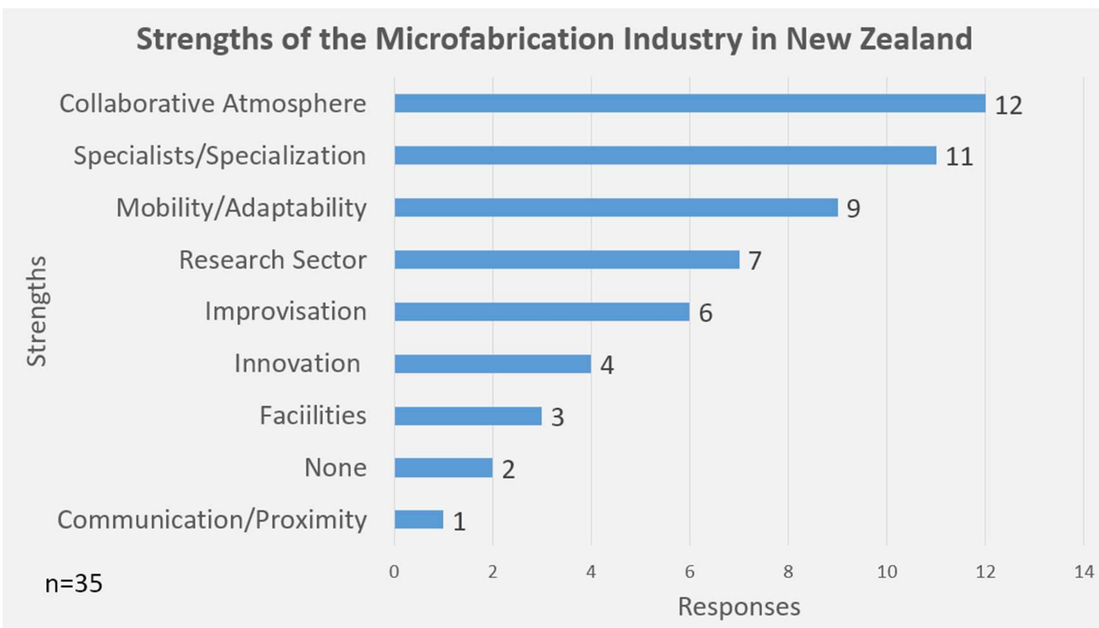

Figure 4.3: Interviewee Identified Strengths of the Microfabrication Industry in New Zealand

Figure 4.3 displays the perceived main strengths of the current microfabrication industry ordered by the number of the interviewees who identified them. The three main strengths identified were having a collaborative atmosphere, having a variety of quality specialists and areas of specialization, and having the advantage of mobility and flexibility.

As Figure 4.3 depicts, the collaborative atmosphere is the largest perceived strength of the current microfabrication industry based on the number of the interviewees that identified it. While this is only 34% of the total number of interviewees, this is still a significant percentage since the team's questions never asked about collaboration in the microfabrication industry. Having a good collaborative environment is essential to cluster success and if that already exists in New Zealand, as this data suggests, it will greatly increase the chance of forming a successful cluster. Leo Browning, a PhD student from Victoria University of Wellington, highlighted the importance of collaboration to a small country like New Zealand.

> *Why I think the collaborative environment is so important is that there [are] a lot of big companies around the globe, big countries, big research economies, and there is no reason why a small country, small economy, small research group can't contribute but it needs to be in a collaborative way in order to kind of best engage on a global scale. (L. Browning, personal communication, January 20th, 2016)*

When asked about the current strengths of the microfabrication industry, 31% of the interviewees said that they considered specialists and specialization to be a strength of the microfabrication industry in New Zealand. Again this is significant because the team did not specifically ask about specialization or specialists. Having numerous specialists in various different areas of specialization can potentially help a cluster by giving the cluster a wider breadth of knowledge and lower the chances of falling into a competency trap.

Figure 4.3 illustrates that the third largest strength that the interviewees identified is mobility/adaptability. Mobility refers to the microfabrication industry's ability to easily ship products due to the small size of microfabricated elements. Adaptability refers to the ability of this industry to switch specializations and focuses quickly and adapt to changing trends. Mobility was a strength that the team did not think of when we initially created our interview questions. Being able to ship microfabrication products easily and cheaply due to their weight and size could give the microfabrication industry in New Zealand an advantage over other New Zealand industries.

4.2.2 Weaknesses of the Microfabrication Industry in New Zealand

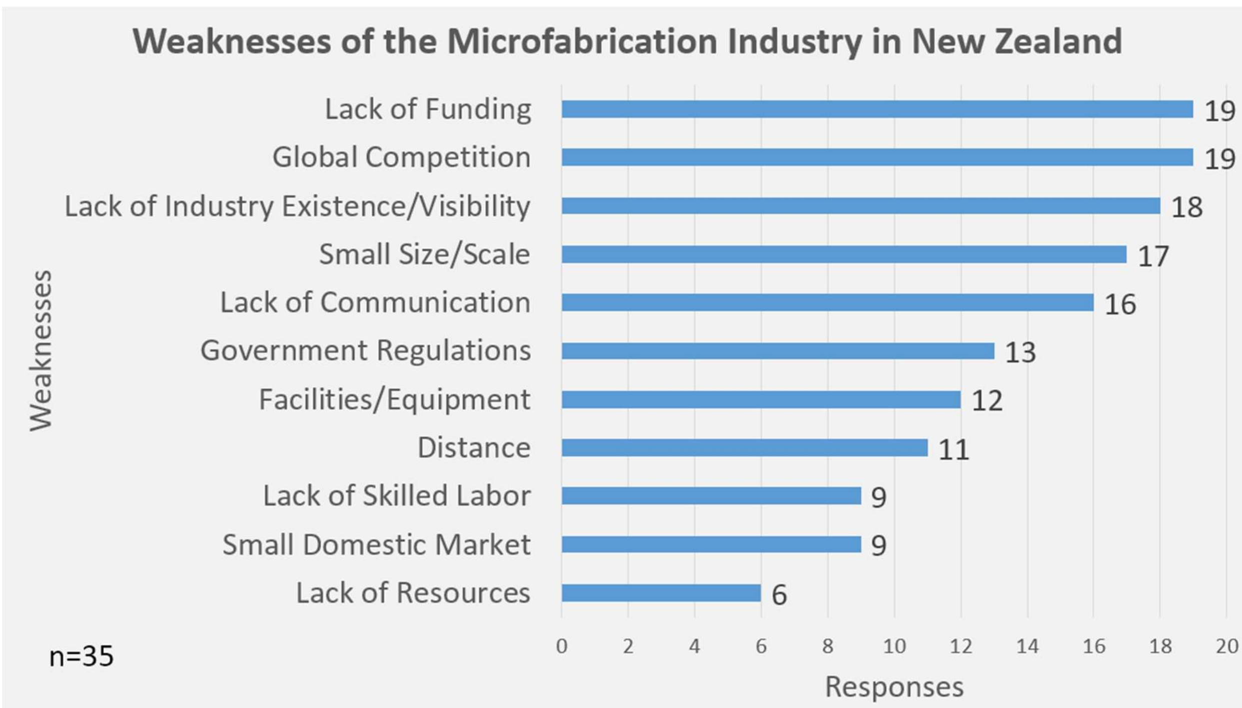

Figure 4.4: Interviewee Identified Weaknesses of the Microfabrication Industry in New Zealand

Weaknesses Mentioned	**Researcher**		**Manufacturer**		**Student**		**Supplier**		**Other**		**Total**	
Small Size / Scale	11	61%	4	57%	1	20%	1	50%	0	0%	17	49%
Lack of Funding	11	61%	2	29%	2	40%	2	100%	2	66%	19	54%
Facilities / Equipment	8	44%	3	43%	1	20%	0	0%	0	0%	12	34%
Existence	12	66%	4	57%	2	40%	0	0%	0	0%	18	51%
Lack of Communication	7	39%	3	43%	0	0%	1	50%	0	0%	11	31%
Competition	8	44%	7	100%	1	20%	2	100%	1	33%	19	53%
Need for Globalization / No Market in NZ	6	33%	3	43%	0	0%	0	0%	0	0%	9	26%
Distance	5	28%	3	43%	1	20%	2	100%	0	0%	11	31%
Lack of Skilled Labor	4	22%	3	43%	1	20%	1	50%	0	0%	9	26%
Lack of Resources	3	17%	1	14%	1	20%	1	50%	0	0%	6	17%
Government Regulations	7	39%	4	57%	0	0%	1	50%	1	33%	13	37%
Number of Respondents	18		7		5		2		3		35	

Table 4.2: Interviewee Identified Weaknesses of the Microfabrication Industry in New Zealand

The team evaluated the perceived weaknesses of the current microfabrication industry in New Zealand based on responses to Question 16: **"What are the weaknesses of the microfabrication industry in New Zealand?"** and represented the responses in Table 4.2 and Figure 4.4. It is important to note that the team did not prompt for any of the specific weaknesses of the industry and that we based all weaknesses on the interviewees' responses. Additionally, note that interviewees were able to give as many or as few weaknesses as they wished in the interviews and the total count of weaknesses does not necessarily match the number of interviewees.

Figure 4.4 provides the weaknesses of the current microfabrication industry based on the number of the interviewees who identified them. The four main weaknesses are lack of funding, industry existence, global competition, and the small population size of the country and scale of production.

Figure 4.4 shows that 54% of the interviewees considered lack of funding to be a weakness of the current microfabrication industry in New Zealand. Table 4.2 reveals that 61% of researchers, 29% of manufacturers, 40% of students, and 100% of suppliers said that lack of funding is a weakness of the current microfabrication industry in New Zealand. This data suggests that this is a major problem for the industry. Lack of funding could hinder the formation of a cluster but it could also give individual organizations a reason to join a cluster initiative. It may be the right choice for some organizations to join the cluster if there is a sharing of resources such as funding.

Figure 4.4 illustrates that 49% of the total interviewees indicated that size and scale of the country and production were weaknesses of the current microfabrication industry in New Zealand. Table 4.2 reveals that 50% or more of three separate stakeholder groups identified the population size of New Zealand and scale of production as a weakness of the microfabrication industry in the country. There is no direct solution to the problem of New Zealand's small population size as there is no way to suddenly and drastically increase the local population. There may be ways to indirectly relieve the problems associated with having such a small national population. Cather Simpson, Director of the Photon Factory in Auckland, touched on the weaknesses posed by limited funding and small size.

> *The hardest thing about New Zealand in general, and especially for high tech things like microfab, is that we're far away and we're small. So a lot of the cutting edge microfabrication stuff is quite expensive and we simply can't afford to have a lot of it, if we have it at all. (C. Simpson, personal communication, January 26, 2016)*

Limited funding for state-of-the-art equipment and small population of the country may contribute to New Zealand's lack of competitiveness with other countries. Figure 4.4 displays that 54% of the total interviewees considered global competition to be a weakness of the current microfabrication industry in New Zealand. Global competition refers to difficulties competing in foreign markets. All of the manufacturers cited global competition as a weakness of the current microfabrication industry in New Zealand. Compared to other stakeholder groups, this issue was much more prominent for the manufacturers. This is likely because manufacturers are the organizations dealing with commercialization and trying to sell their products in global markets.

Figure 4.4 shows that 51% of the total interviewees considered the lack of existence of a developed microfabrication industry in New Zealand and visibility of the industry to be a weakness of the industry. Table 4.2 reveals that both a majority of researchers and manufacturers see this as a major weakness for the industry. This implies that organizations need to do more to promote commercial businesses better. "Competing against nations that have lower cost of operation than we do makes it very challenging." (Anonymous C, personal communication, 2016) Because it is often cheaper to produce devices in other countries like China that have more resources and more relaxed labor laws, it can be very difficult for New Zealand companies to compete globally.

4.2.3 Effect of Microfabrication on Technology

The team evaluated the perceived effects of microfabrication on technological progress, specifically the increased efficiency of technology, based on responses to Question 11: **"How has miniaturization changed technology in New Zealand?"** and represented the responses in Table 4.3 It is important to note that the team did not prompt for any specific effects of microfabrication on technology. Table 4.3 represents efficiency as a result of the number of voluntary responses about the positive effect of microfabrication on technological efficiency.

Effect of Microfabrication on Technology	**Researcher**		**Manufacturer**		**Student**		**Supplier**		**Total**	
Efficiency	8	44%	4	57%	2	40%	1	50%	15	43%
Number of Respondents	18		7		5		2		35	

Table 4.3: Interviewee Responses Pertaining to Added Efficiency

The data in Table 4.3 suggests that is no great difference between the stakeholder groups' opinions concerning the effects of microfabrication on the efficiency of technologies and devices, with roughly half of each stakeholder group commenting on the topic. CEO of Revolution Fibers, Iain Hosie gave an example of the scale of the efficiency added through microfabrication: "One kg of polymer can make a fiber that would reach the sun because it's so fine" (I. Hosie, personal communication, January 26th, 2016). Given that the team did not prompt for responses on the efficiency, it is important to note the high percentage of responses that chose to highlight this specific effect on technology. This data suggests that the added efficiency is a commonly recognized benefit of microfabrication, and that it is sufficiently important to the industry that many of the interviewees specifically mentioned it.

4.2.4 Future Outlook of the Microfabrication Industry in New Zealand

It was important to assess the interviewees' perceptions about the future outlook of the microfabrication because if these interviewees had a negative outlook for the future, they may be unwilling to join a cluster initiative. The team evaluated perceptions about the future outlook of the microfabrication industry based on responses to Question 12: **"What do you imagine microfabrication in New Zealand to be like in 5-10 years?"** and Question 13: **"How do you see ongoing miniaturization affecting the future in 5-10 years?"** and represented the responses in Figure 4.5. Because some of our interviews were digital and we did not require the interviewees to answer all the questions, 2 of the 35 interviewees did not respond to both Questions 12 and 13. Thus, Figure 4.5 represents 33 total interviewees.

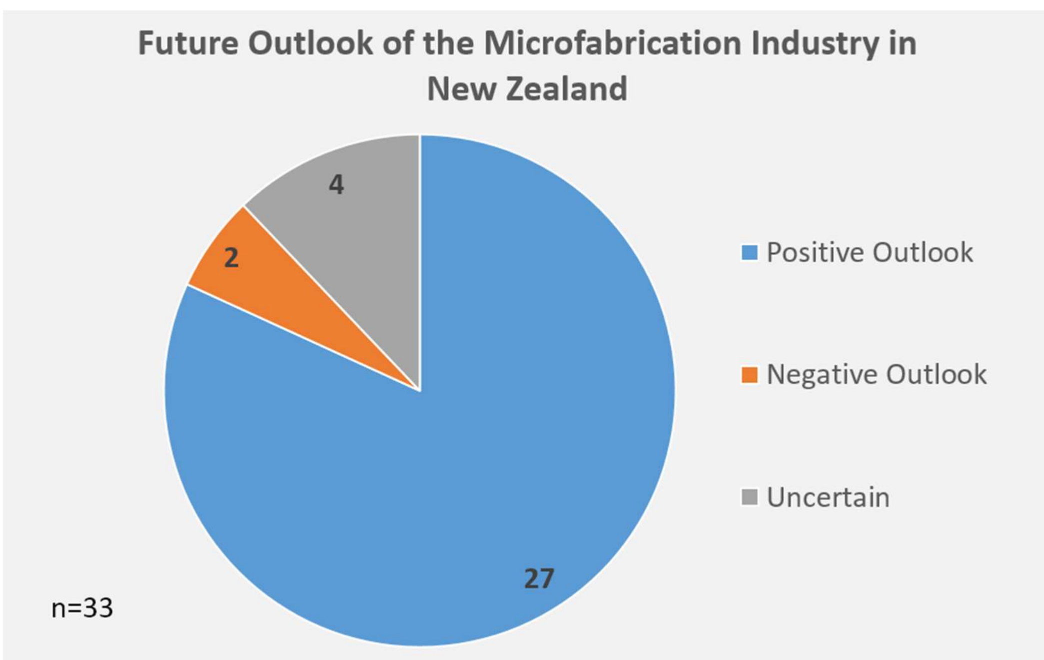

Figure 4.5: Interviewee Perception of Future Outlook of the Microfabrication Industry in New Zealand

This graph illustrates that a significant majority of the interviewees had a positive outlook on the future of the microfabrication industry in New Zealand, with only 6% of the interviewees having a negative outlook on the future of the microfabrication industry in New Zealand and 82% having a positive outlook. This suggests that many of the stakeholders currently in the industry see microfabrication either becoming stronger in the future, or having more of an impact on New Zealand. Researcher Alan Coulson reinforced this idea, stating, "obviously it's a technology of high potential future benefit to New Zealand. It's an area where good researchers can really push boundaries of what's possible and therefore can really help drive business opportunities" (A. Coulson, personal communication, January 28th, 2016).

4.2.5 Plans after Graduation

The team evaluated graduate students' future plans concerning whether or not they would continue their careers in New Zealand or in other countries based on responses to Questions 48: **"Are you looking to get a job in New Zealand or somewhere else?"** Question 49: **"If you are looking to get a job in another country, why?"** and Question 50: **"If you are looking to get a job in New Zealand, why?"** and represented the responses in Table 4.4 and Table 4.5. We only asked these questions to the student stakeholder group, and as such there were only five responses. The lack of responses reduces the confidence in a strictly quantitative sense. From the interview responses, the team generated specific reasons for each action (staying and leaving), as well as common weaknesses of the microfabrication industry here in New Zealand.

n=5	**Family / Significant Other**	**The Environment**	**The Culture**
Students	3	1	2

Table 4.4: Student Identified Reasons Why Students Want to Stay in New Zealand

Table 4.4 displays that the reasons why the students would want to stay in New Zealand relate to family and intrinsic things about New Zealand. The data suggests that people love New Zealand for both its culture and environment, as Ph.D. student Leo Browning states, "a lot of people live here and a lot of people choose to move here from other places because it's a beautiful place. It's got a lot of natural beauty, it's not super crowded…." (L. Browning, personal communication, January 20th, 2016) The data also shows that the response of staying for family or a significant other was just as common.

n=5	**No Jobs**	**Poor Facilities**	**Not Competitive Globally**	**Family / Significant Other**	**Desire to Travel**
Students	1	0	0	2	1

Table 4.5: Student Identified Reasons Why Students Would Leave New Zealand

Table 4.5 indicates that the most common response to wanting to leave was the same reason for staying: to be closer to family.

4.3 Objective 2

The project's second objective was to determine the willingness of New Zealand organizations to join a cluster initiative and to determine the potential barriers hindering the formation of the cluster. From the semi-structured interviews that the team conducted with members from each of the stakeholder groups, the team pulled out three key categories to concisely represent the data that we collected with respect to our second objective. The three categories that the team used are: "Willingness to Join a Cluster," "Barriers to the Formation of a Microfabrication Cluster," and "Current Knowledge of Clusters." Sections 4.3.1 to 4.3.3 display the data that the team gathered from the interviews and the analyses of this data.

4.3.1 Willingness to Join a Cluster

The team evaluated the willingness of organizations to join a microfabrication industry cluster initiative in New Zealand based on responses to Question 20: **"How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication field? Why or why not?"** and represented the responses in Figure 4.6 and

Table 4.6. We did not ask Question 20 to 1 of the 35 interviewees, who worked for the New Zealand Treasury, as he was not a potential microfabrication cluster member. Hence, Figure 4.6 and Table 4.6 indicate only 34 total respondents. It is important to note that the team did not prompt for any of the specific conditions for joining the cluster and we based the conditions represented on the interviewees' volunteered responses. It is also important to note that interviewees were able to give as many or as few conditions as they wished in the interviews, so the total count does not necessarily match the number of interviewees.

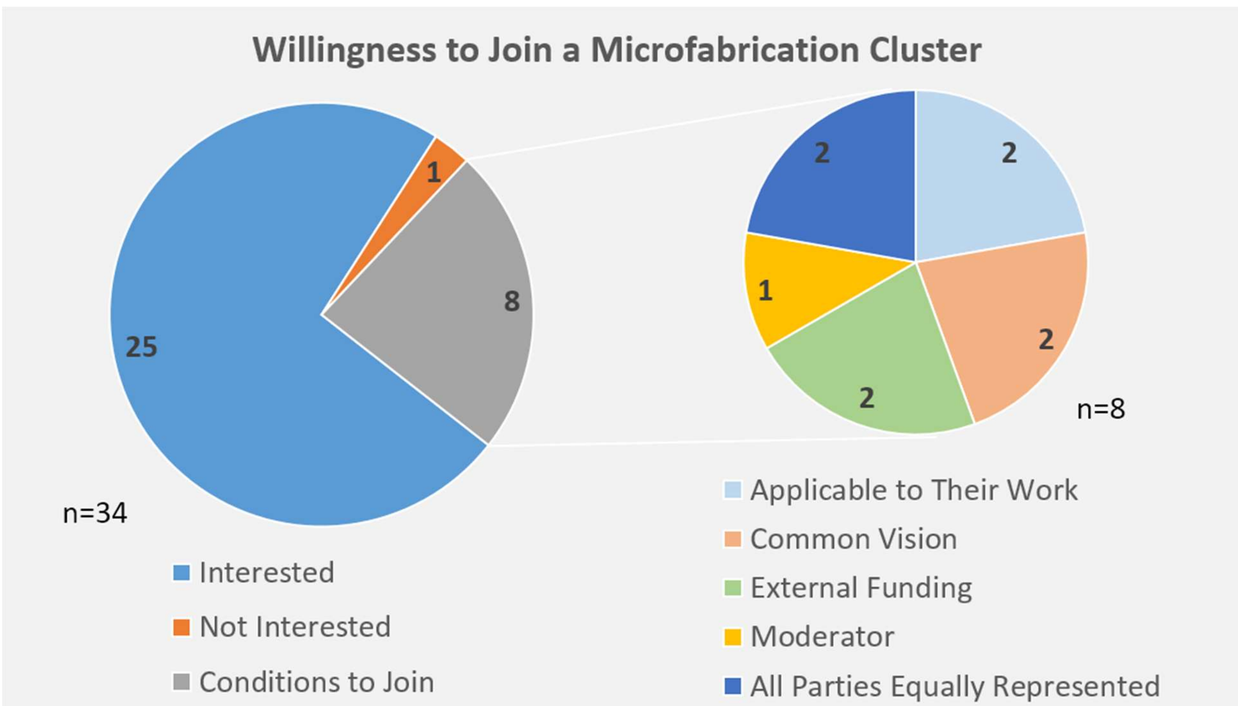

Figure 4.6: Willingness to Join a Microfabrication Cluster and Additional Needs

Interest Levels, Contingencies, and Skepticism	**Researcher**		**Manufacturer**		**Student**		**Supplier**		**Other**		**Total**	
Interested	15	83%	3	43%	4	80%	1	50%	2	66%	25	71%
Not Interested	1	6%	0	0%	0	0%	0	0%	0	0%	1	3%
Conditions to Join	2	11%	4	57%	1	20%	1	50%	0	0%	8	23%
Applicable to Their Work	2	11%	0	0%	0	0%	0	0%	0	0%	(2)	(25%)
Mediator	0	0%	1	14%	0	0%	0	0%	0	0%	(1)	(13%)
Common Vision	0	0%	2	29%	0	0%	0	0%	0	0%	(2)	(25%)
External Funding	0	0%	2	29%	0	0%	0	0%	0	0%	(2)	(25%)
All Parties Equally Represented	0	0%	0	0%	1	20%	1	50%	0	0%	(2)	(25%)
Skepticism of Cluster Success	3	9%	3	9%	0	0%	0	0%	0	0%	6	18%
Number of Respondents	18		7		5		2		3		35 (8)	

Table 4.6: Interviewee Willingness to Join a Microfabrication Cluster

In the "Total" column in Table 4.6, some figures are surrounded by parentheses. These figures represent the specific conditions mentioned by those interviewees who were interested in joining a cluster, but mentioned contingencies to joining. Because not every interviewee responded in such a manner, the total number of respondents is out of 8, and not 35. Table 4.6 depicts that 74% of interviewees said that they would be willing to join a microfabrication cluster initiative in New Zealand, but did not mention any conditions of their own on how the proposed cluster would run. An additional 24% of interviewees said that they would be willing to join the cluster if the proposed cluster has certain aspects in it. One interviewee said he was not willing to join the proposed cluster initiative because he saw his role in academia and did not see a need to join a cluster. Having such a large percentage of individuals who are willing to join the microfabrication cluster initiative is very encouraging for the feasibility of creating such a cluster.

As Table 4.6 reveals, 4 of the 7 manufacturers (57%) were in the group of 8 interviewees who wanted something more out of the cluster before committing. This means that 50% of the interviewees who wanted something more were manufacturers. This suggests that manufacturers are less flexible when it comes to terms on which they will enter a microfabrication industry cluster initiative in New Zealand. It could be detrimental for the cluster if one group has rigid terms to join, because if they are not convinced to join then the cluster will not function. Among them, these 8 interviewees specified five different conditions for the cluster initiative:

- It must be applicable to the work that they already do or plan to do.
- There must be a common vision for the cluster as a whole.
- There should be a mediator or objective third party to go between clients and the proposed cluster.
- All parties must be equally represented in the cluster.
- There should be some form of external funding for this cluster.

For the most part, interviewees mentioned these conditions in approximately the same amounts. It is important to note that 6 of the 34 interviewees were skeptical of the proposed cluster's success.

4.3.2 Barriers to the Formation of a Microfabrication Cluster

The team evaluated the barriers to the formation of a microfabrication cluster based on responses to Questions 17: **"How do you feel about collaboration with other organizations?"** Question 18: **"What do you know about industry clusters and how do you see a cluster operating?"** Question 19: **"How aware are you of the microfabrication facilities in New Zealand?"** and Question 22: **"What types of government regulations affect your work?"** and represented the responses in Table 4.7 and Table 4.8. The team compiled the list of specific barriers from the interview responses. The tallies from each of the responses do not add up to the number of responses in each stakeholder group, as one interviewee could mention more than one barrier.

Identified Barriers	**Researcher**		**Manufacturer**		**Student**		**Supplier**		**Other**		**Total**	
Lack of Funding for Cluster	3	17%	1	14%	0	0%	0	0%	1	33%	5	14%
Lack of Common Vision	0	0%	2	29%	0	0%	1	50%	0	0%	3	9%
Competition	3	17%	2	29%	0	0%	1	50%	0	0%	6	17%
Lack of Communication	7	39%	5	71%	2	0%	1	50%	1	33%	16	46%
Number of Respondents	18		7		5		2		3		35	

Table 4.7: Perceived Barriers to the Formation of the Microfabrication Cluster

Table 4.7 suggests that the largest barrier to the formation of a microfabrication cluster in New Zealand is the lack of communication between the different organizations and the different sectors, with 46% of interviewees mentioning it as a hindrance. As these responses were unprompted, this may also suggest that this barrier to the formation of a cluster is one that is most impactful to the individual organizations. With 71% of manufacturers and 39% of researchers mentioning the lack of communication, it was the most common response. The data suggests that the existence of internal competition, a lack of funding to support an industry cluster, and a lack of a common vision are less significant barriers to the formation of the microfabrication cluster in New Zealand than the lack of communication between potential cluster members. This lack of communication may arise due to the fact that the different sectors are relatively unaware of each other, as seen in Table 4.8.

Another barrier to the formation of a microfabrication cluster suggested by the data is the existence of competition on a national level. With 29% of manufacturers, 17% of researchers, 50% of suppliers, and 17% of all of the interviewees, the data suggests that this is primarily a concern within both the research and manufacturing sectors. Researchers often compete against each other for government grants, while manufacturers compete with their products. Some of the competition could also be due to intellectual property concerns and the competition for clients. One researcher who we interviewed commented on the internal competition between researchers over the available funds by saying, “if we compete on the small amount of funds that [are] available, we all lose” (M. Alkaisi, personal communication, February 4th, 2016). The data may also suggest the lack of funding for a cluster (14% of respondents) as a possible barrier to the formation of the microfabrication cluster. The data shows that the students and suppliers (0%) did not see the lack of funding as impacting the formation of a cluster in microfabrication. This data may suggest that students in the microfabrication industry in New Zealand are not yet aware of the levels of funding on a national level.

Awareness Level	**Researcher**		**Manufacturer**		**Student**		**Supplier**		**Other**		**Total**	
Aware	6	33%	0	0%	0	0%	1	50%	0	0%	7	20 %
Partially Aware	10	55%	4	57%	3	60%	0	0%	1	33%	18	51 %
Not Aware	2	11%	3	43%	2	40%	1	50%	2	66%	10	29 %
Number of Respondents	18		7		5		2		3		35	

Table 4.8: Interviewee Awareness of the Microfabrication Industry

In the context of this section, the term awareness refers to the interviewees' knowledge of the existence of other microfabrication facilities in New Zealand. As Table 4.8 indicates, a majority of the interviewees are only partially aware of the microfabrication industry in New Zealand. This classification included interviewees who had a knowledge of the research sector in New Zealand, such as the universities and government facilities like Victoria University of Wellington and Callaghan Innovation, but little to no knowledge of the manufacturing sector. Table 4.8 also reveals that 29% of the interviewees were not aware of the microfabrication industry at all, or had very limited knowledge of it. The team only classified 20% of the interviewees as aware of the industry. By aware, the team means that the interviewee knew most of the microfabrication research sector currently in New Zealand as well as various members in the microfabrication manufacturing sector. Researchers dominate the proportion of the industry that is aware, 86% of aware interviewees being from the research sector. Also the fact that only 20% of interviewees are aware of the other members of the microfabrication industry in New Zealand suggests that there is a disconnect between the different sectors of the industry in New Zealand. This is not good for the formation of the potential microfabrication cluster, as for a cluster to succeed, the different organizations need to be knowledgeable of the other organizations and what they are doing or researching. A disconnect between the different sectors of the microfabrication industry is a potential barrier to the formation of the proposed microfabrication cluster in New Zealand.

4.3.3 Current Knowledge of Clusters

The team evaluated the current knowledge of industry clusters based on responses to Question 18: **"What do you know about industry clusters and how do you see a cluster operating?"** and represented the responses in Figure 4.7. Not every interviewee gave a response to this question because the team had not asked this question in the first four interviews. As the result of editing our interview questions after some of the initial interviews to better address our second objective, the team did ask this question to the remaining 31 interviewees. This is why the number of respondents to this question does not add up to the sample size of 35.

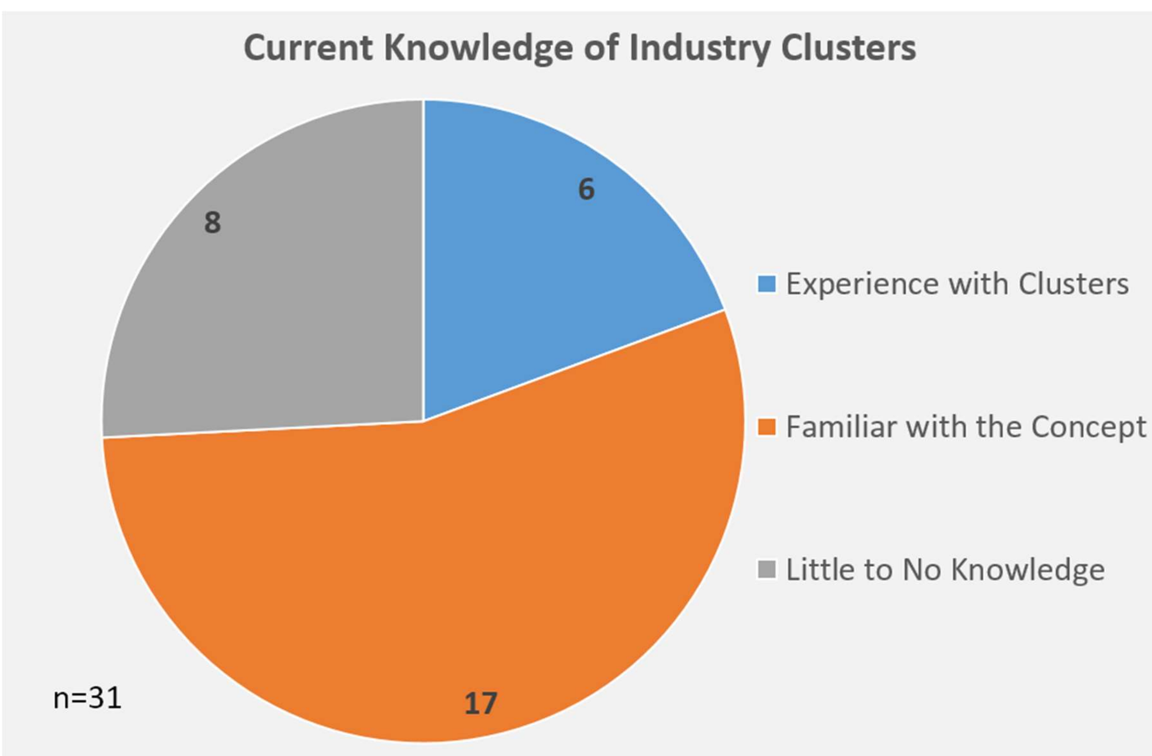

Figure 4.7: Interviewee Current Knowledge of Industry Clusters

Figure 4.7 reveals the overall knowledge of clusters of the individuals that the team interviewed. A total of 23 interviewees were at least familiar with clusters with 6 of them having personal experience with clusters. This experience could be either being a member of a cluster, or even being involved in the process for creating a cluster. Figure 4.7 also indicates that 26% of the interviewees showed or claimed to have little to no knowledge of industry clusters. This data suggests that while the interest and willingness may be there, the knowledge about clusters is lacking. This could be a problem moving forward with the formation of the cluster, because if the individuals making up the cluster do not have solid understanding of what goes into a cluster, then it could compromise the stability of the cluster.

4.4 Objective 3

The project's third objective was to identify the perceptions of industry members concerning potential environmental and cultural impacts that the microfabrication industry may have in New Zealand. From the semi-structured interviews the team conducted with members from each of the stakeholder groups, the team pulled out four key categories to concisely represent the data that we collected with respect to our third objective. The four categories that the team chose are: "Environmental Concerns with Microfabrication," "Handling of Environmental Concerns," "Openness to and Awareness of Technology and Microfabrication", and "Maori Cultural Concerns with Microfabrication". Sections 4.4.1 through 4.4.4 display the data that the team gathered from the interviews and the analyses of this data.

4.4.1 Perceived Environmental Concerns with Microfabrication

The team evaluated the perceptions of the effects of microfabrication on the environment based on responses to Question 21: **"Are there any environmental concerns with**

microfabrication and if so, what are they and how are they dealt with?" and represented the responses in Table 4.9. The team did not ask this question to two of our interviewees. The team compiled the list of perceived environmental concerns from the interview responses. The tallies from each of the responses do not add up to the number of responses in each stakeholder group, as one interviewee could mention more than one environmental concern.

	Researcher		**Manufacturer**		**Student**		**Supplier**		**Other**		**Total**	
Nanotechnology	6	38%	0	0%	0	0%	0	0%	1	33%	7	21%
Solvents	3	19%	1	14%	0	0%	0	0%	0	0%	4	12%
Chemicals	9	56%	4	57%	3	60%	2	100%	0	0%	18	54%
Other	3	19%	0	0%	1	20%	0	0%	0	0%	4	12%
Number of Respondents	16		7		5		2		3		33	

Table 4.9: Interviewee Perceived Environmental Concerns with Microfabrication

Table 4.9 shows the data collected from the interviewees about the various perceived environmental concerns from our interviewees that exist within the microfabrication industry in New Zealand. The two most reoccurring environmental concerns are nanotechnology and the various hazardous chemicals used, such as: hydrofluoric acid, fluorocarbons and sulfur hexafluoride, within the multiple processes in the microfabrication of structures and devices, followed by the use of solvents. Some interviewees discussed the potential negative effects of nanotechnology citing the dispersion and inhalation of nanoparticles. The interviewees cited these as concerns because the scientific community does not yet know the impact of such a new technology on the environment and on people. The common perceived environmental concern that had a similar response over all stakeholder groups was hazardous chemicals with 50% or more of every stakeholder group except other experts identifying this as a concern.

4.4.2 Levels of Concern about the Impact of the Microfabrication Industry on the Environment

The team evaluated the interviewees' levels of concern about the impact of the microfabrication industry on the environment based on the responses to Question 21: "**Are there any environmental concerns with microfabrication and if so, what are they and how are they dealt with?**" and represented the responses in Figure 4.8. The team did not ask this question to two of our interviewees because we edited the interview questionnaire to include this question after the first two interviews. This is the reason that the sample size for this graph is 33. It is important to note that five of the interviewees chose to not answer this question. It is also important to note that interviewees who said that they were not worried about the concerns of the microfabrication industry also gave what the potential concerns were, which were represented in Table 4.9

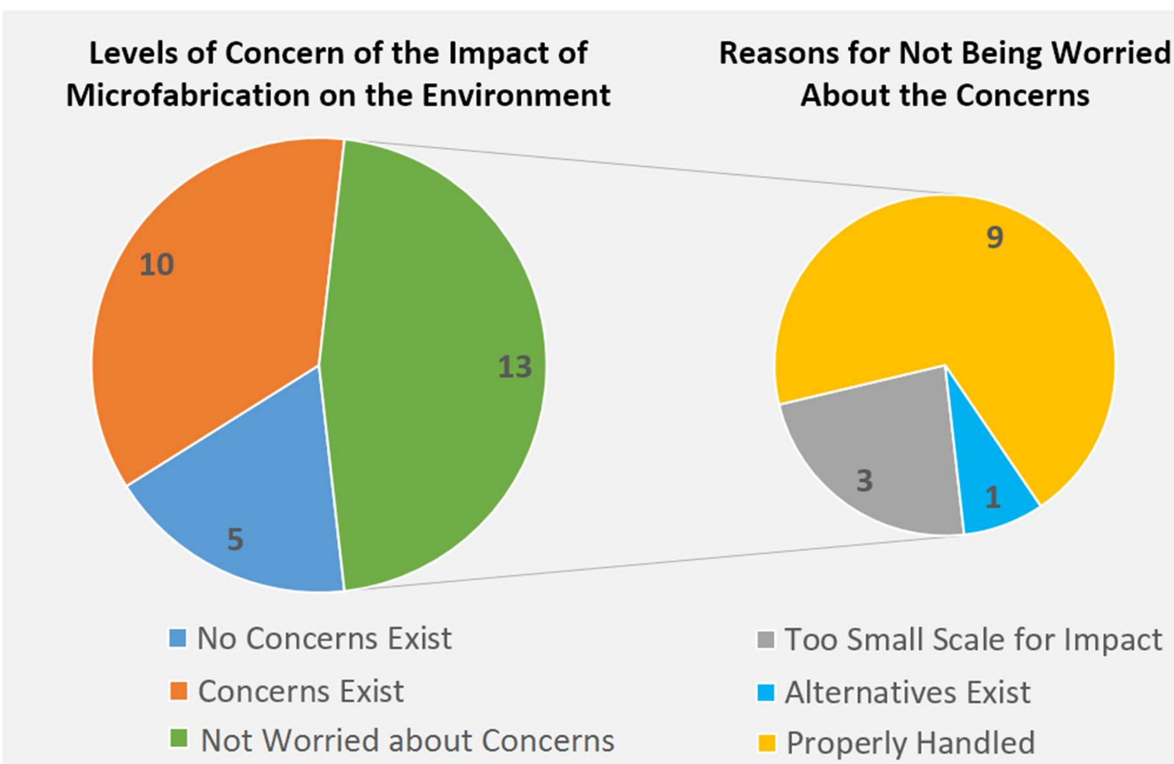

Figure 4.8: Levels of Concern of the Impact of Microfabrication on the Environment

Figure 4.8 shows the responses from the interviewees about their level of concern about the impact of the microfabrication industry on the environment. Out of the 33 interviewees that the team asked this question to, 70% said that there are concerns to the environment. These concerns include hazardous chemicals such as hydrofluoric acid, fluorocarbons and sulfur hexafluoride, solvents, the dispersion of nanoparticles into the air, and heavy metals. However, 57% of these interviewees, or 39% of all of the interviewees to whom the team asked this question, stated that they were not worried about these concerns for a variety of reasons. The largest of these reasons, at 69% of those who responded as not being worried, was that good lab practices and common sense nullifies the harmful effects that the previously mentioned concerns may have on the environment. The second largest reason, at 23%, was that due to the small scale of production in terms of microfabrication in New Zealand, the amount of waste generated was not of a large enough volume to be significantly harmful. This data suggests that many individuals in the microfabrication industry understand that there are environmental concerns, but a majority of those interviewees, who said that there were concerns to the environment, are not worried about those concerns. This data also suggests that 15% of the individuals that we interviewed either did not know of the impacts that many of the other interviewees mentioned, or that they possibly thought that the concerns to environment were not sufficient to warrant any action.

4.4.3 Perceived Societal Impacts of Microfabricated Technology in New Zealand

The team evaluated the perceived societal impacts of microfabricated technology in New Zealand based on responses to Question 14: **"How do you think miniaturized technology impacts society in New Zealand?"** and represented in Figure 4.9. It is important to note that the team did not specifically prompt for any of the specific societal impacts of the industry and that we based all specific impacts on the interviewees' responses.

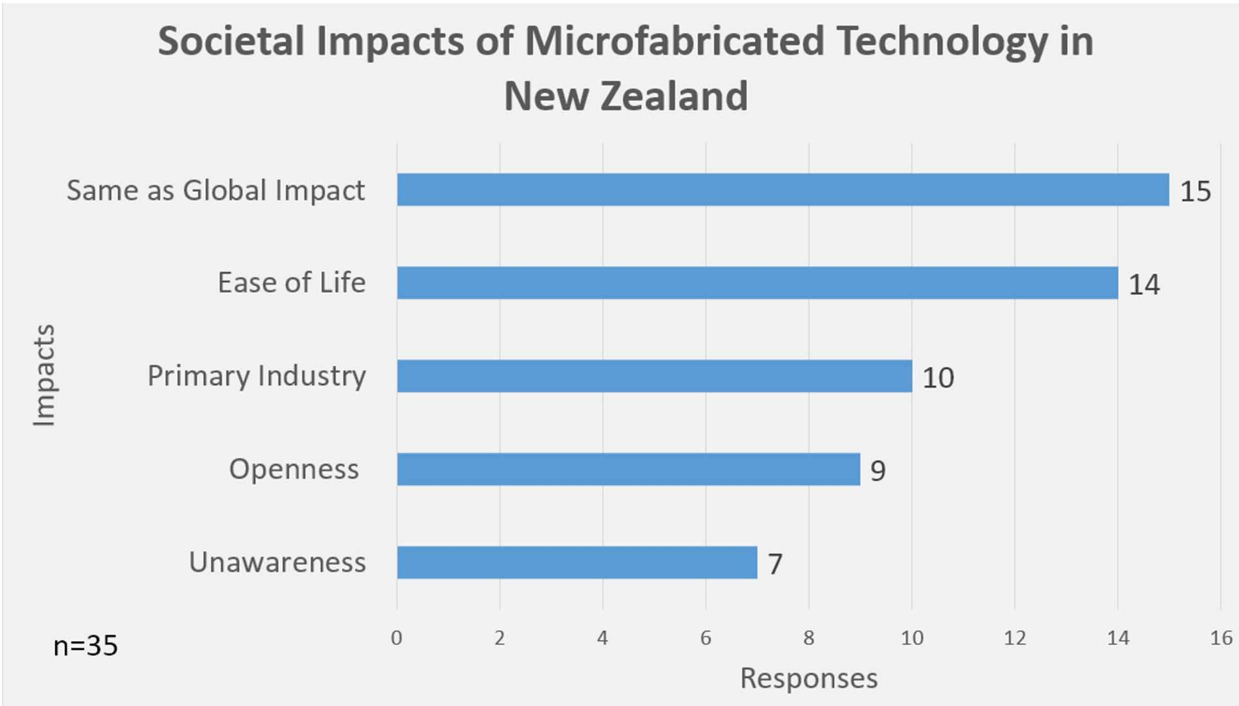

Figure 4.9: Interviewee Perceived Societal Impacts of Microfabricated Technology in New Zealand

Figure 4.9 shows 43% of interviewees believe that the impacts that microfabrication has on New Zealand are the same as the impacts microfabrication has had worldwide, such as making devices smaller and more efficient. Figure 4.9 also displays that 40% of interviewees believe that microfabricated technology is beneficial to New Zealanders and makes aspects of their lives easier. This suggests that the microfabrication is a helpful technology in New Zealand, however, Figure 4.9 also suggests that the interviewees may believe that New Zealanders may not realize the benefits with 20% of interviewees saying that the general public is unaware of microfabrication technology. While 20% is not a large percentage it is still significant as none of the responses to this question were prompted. One manufacturer echoed the views of many interviewees, stating:

I don't think most of our society is aware. But, you know, your cell phone's built basically on microfabrication and there's accelerometers in there. But the Fitbit watches that everyone's using comes about because of microfabrication facilities. (Anonymous G, personal communication, February 3, 2016)

This interviewee believes that although microfabrication has impacted many aspects of everyday life, many people are unaware of microfabrication and its effects. However, this does not mean that society is not open to new technology that microfabrication can provide. From our analysis of these responses, we discovered that 7 of the 35 interviewees observed that New Zealand society is generally unaware of how microfabrication and miniaturization of technology affects their everyday lives. In addition, 9 out of the 35 interviewees mentioned that they believed that New Zealand society is open to high-tech technology. Although these are not high percentages of the total interview pool, they are still significant because we did not prompt the interviewees to comment on the awareness and openness of society to technology.

The fact that this many interviewees commented on New Zealand society's openness to high tech without the team prompting them could indicate that much of the population is actually open to using high tech devices, such as those created through microfabrication. However, these perceptions of our interviewees could be biased based on their own involvement in the microfabrication field and may not represent the actual cultural attitude of New Zealanders to high-tech technology. This could be important for the success of the cluster initiative because support for the industry may allow it to flourish.

This data suggests that the interviewees think that much of society is not aware of how microfabrication impacts their everyday lives and may be unappreciative of microfabricated technology in general. Lack of awareness and appreciation may limit the amount of people pursuing careers in microfabrication and stunt the growth of the industry. On the other hand, a cluster may combat this lack of awareness by catalyzing more discussion of microfabrication and incorporation of this technology into other industries.

Figure 4.9 depicts that 10 out of 35 interviewees answered the question “How does microfabricated technology impact society in New Zealand?” by talking about New Zealand’s economy and its focus on primary industries such as agriculture \. This suggests that when the interviewees thought about New Zealand society they thought of New Zealand as a society that is focused more on industries like agriculture than on secondary industries like microfabrication. Ben O’Brien, CEO of Stretchsense, states, “New Zealand is still transitioning away from this agricultural thing that’s still a dominant sector of the economy” (B. O’Brien, personal communication, January 26th, 2016). This current focus on primary industries could hinder the development of the microfabrication industry in New Zealand.

4.4.4 Perceptions of Maori Cultural Concerns with Microfabrication

The team wanted to determine the perceptions of our interviewees with respect to the cultural concerns in New Zealand society with microfabrication and the processes involved in microfabrication. To do this, we looked to evaluate the opinions of specific groups that may have cultural concerns. With Maori coming from a different background than Pakeha, we believed that Maori might disapprove of high tech-tech industries due to different cultural views. The team retrieved this information based on the responses to Question 51: **“If you consider yourself Maori, do you see any major cultural conflicts with microfabrication/high-tech fields?”** The team interviewed two Maori and both perceived that there are groups of more traditional Maori who would disapprove of some microfabrication processes including processes that interfere with God’s domain, such as affecting the body in ways like injecting nanotechnology. They expressed that there are conservative, traditional views in every culture, however, which means that there will always be people who view new technologies unfavorably. In reference to Maori adapting to change, a Maori who works for the Treasury stated:

> *I think it's not a simple thing to say 'Ah technology, it's against our culture,' because we've adapted. Every time. At the same time, I'm acknowledging that there are people that will say, 'We don't do that! 75 years ago that's not how our people did it.' And lots of cultures are like that. Lots of people are like that but ... human beings are innovators, we're adapters, we don't just stay in one place forever and ever and ever (A. Tibble, personal communication, January 14, 2016).*

Tibble was saying that it is unfair to say that New Zealand is against technology or that the Maori don't like technology because this society has always adapted to change. Both Maori interviewees had perceptions that microfabrication does not present a significant cultural issue any more than similar industries in other countries. That being said, it is important to note that these are the opinions of only two Maori, both of whom work in organizations having a vested interest in the betterment of the microfabrication industry or the economy as a whole. Also, due to the extremely small sample size of only two experts, the team cannot make any conclusions based on their responses. If there are any cultural conflicts, this field may not receive much support.

5 Recommendations

We believe that the microfabrication industry cluster initiative in New Zealand is feasible because the conditions in the country are already hospitable to aid the success of the cluster. Our interviewees generally agreed that one of the major strengths of the industry is the willingness of industry members to collaborate, which is an important foundation for a successful cluster. There may be a lack of communication between potential cluster members and not everyone in the industry is aware of each other's existence, but many have the desire to collaborate. Of the interviewees we asked, a vast majority (97%) were willing or interested in joining a microfabrication industry cluster initiative in New Zealand. Our specific recommendations for Callaghan Innovation are as follows:

- To form a successful microfabrication cluster in New Zealand, the team recommends that Callaghan Innovation make contact with all of the interviewed companies and organizations and create open channels of communication between them, so as to raise awareness within and between the industry sectors. Callaghan Innovation can achieve this by holding large central meetings where all potential cluster members attend either in person or by video conference and can openly discuss the way the cluster should run and move forward. This can also help build relationships between the organizations and improve the communication gap between the different industry sectors.
- Organizations interested in the proposed cluster have suggested several things including the use of a mediator, having a common vision for the cluster, obtaining funding external to the cluster, keeping the cluster applicable to the individuals' work, and representing all cluster members equally. Our investigation suggests that these are the topics that the organizations should discuss with the other organizations in the industry.

- Our findings indicate that the key perceived strengths of the microfabrication industry in New Zealand are the variety of specialists and organization specializations, collaborative atmosphere, adaptability of the organizations, and mobility of products. Additionally, the perceived weaknesses of the industry are global competition, population size of the country and scale of production, lack of funding, and lack of a developed industry. We suggest that organizations prioritize finding solutions to these weaknesses. Such solutions could include pooling together resources; this can be achieved through the formation of a cluster.
- The microfabrication industry has a unique advantage over other industries in New Zealand in that they can export their products more cheaply due to the incredibly small size of the devices produced. This is extremely important for New Zealand specifically because so many of their products need to be exported as a result of reaching domestic market saturation so early. We believe that the future industry cluster should exploit this advantage.
- We recommend that, if formed, the cluster should make efforts to make other New Zealand industries and individual consumers more aware of the microfabricated technology that they already use and the benefits of using more microfabricated technology, possibly through the use of marketing and education. Integrating microfabrication into primary industry may help to create a larger domestic market for microfabrication.

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Appendix A: Interview Questions

Interview

Hello, we are third year engineering students from the US studying at Worcester Polytechnic Institute in Massachusetts. We are carrying out this project assessing the feasibility of creating a microfabrication (by which we mean miniaturized structures or devices with features that may be smaller than a millimeter) cluster in New Zealand as part of our degree program. We will be using this interview in a report that will be published and made available in the public domain. You can remain anonymous and please tell us at the end if there is any information that you do not want published. We hope our report will also be of interest to you.

May we audio record this interview?

- ○ Yes
- ○ No
- ○ N/A

What is your name?

What is the name of your organization?

Would you like to remain anonymous?

- ◯ Yes
- ◯ No

Which part of the microfabrication industry are you personally involved in?

Please select the part you are involved in the strongest.

- ◯ Supplier
- ◯ Manufacturing
- ◯ Research
- ◯ Student

What part of the microfabrication industry is your organization involved in?

- ◯ Supplier
- ◯ Manufacturing
- ◯ Research
- ◯ Student/Education

What is your job title?

What is your job description?

What does the word microfabrication mean to you?

How does microfabrication play a role in your organization?

How has miniaturization changed technology in New Zealand?

What do you imagine microfabrication in New Zealand to be like in 5-10 years?

How do you see ongoing miniaturization affecting the future in 5-10 years?

How do you think miniaturized technology impacts society in New Zealand?

What are the strengths of the microfabrication industry in New Zealand?

What are the weaknesses of the microfabrication industry in New Zealand?

How do you feel about collaboration with other organizations?

What do you know about industry clusters and how do you see a cluster operating?

How aware are you of the microfabrication facilities in New Zealand?

How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication field? Why or why not?

Are there any environmental concerns with microfabrication and if so, what are they and how are they dealt with?

What types of government regulations affect your work?

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Interview

Supplier

How do international trends shape the future of New Zealand microfabrication?

Is your company looking to hire more staff?

What companies do you supply in New Zealand?

« Back   Continue »

Interview

Manufacturing

What are the main applications of your work?

What is your current approach to stay relevant in this rapidly expanding field?

How much money does your organization spend yearly on Research and Development?

How much money does your organization spend yearly on microfabrication in particular?

How many people does your organization have on staff?

How many people does your organization have on staff for microfabrication in particular?

Is your company looking to hire more staff?

How do international trends shape the future of New Zealand microfabrication?

What factors make it difficult to compete in a global market?

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Interview

Research

What is your current approach to stay relevant in this rapidly expanding field?

Is your organization looking to hire more staff?

What factors make it difficult to compete in a global market?

What are the main and potential applications of your work?

How much money does your organization spend yearly on Research and Development?

How much money does your organization spend yearly on microfabrication in particular?

How many people does your organization have on staff?

How many people does your organization have on staff for microfabrication in particular?

« Back   Continue »

Interview

Student

Are you doing any research in microfabrication? If so, what are the applications of your research?

What degree(s) are you pursuing?

Are you looking to get a job in New Zealand or somewhere else?

If you are looking to get a job in another country, why?

If you are looking to get a job in New Zealand, why?

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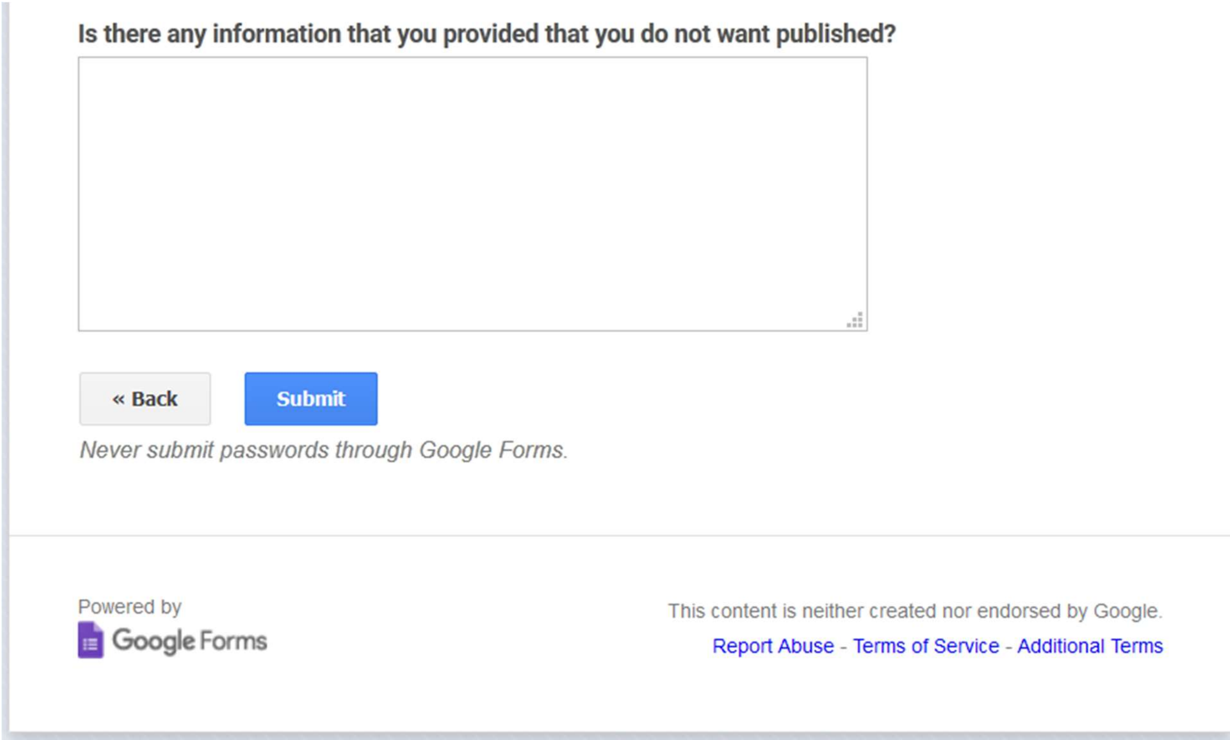
Interview

Thank you!

If you consider yourself Maori, do you see any major cultural conflicts with microfabrication/high-tech fields?

Do you have any additional comments?

Do you know of other companies or research groups in New Zealand that have interest in microfabrication? Who can we contact and what are your connections with these people?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Appendix B: Codes

Organization structure:

- Objectives:
    - Categories
        - Codes
            1. Subcodes
                i. Sub-subcodes

Codes:

- Objective 1
    - Current and Future Outlook
        - Technology and Applications
            1. Sensors
                i. Bio-medical
                ii. Communication
                iii. Environment
                iv. Primary Industries
                v. Other
            2. Actuators
                i. Bio-medical
                ii. Communication
                iii. Environment
                iv. Primary Industries
                v. Other

3 Textiles

i Bio-medical

ii Communication

iii Environment

iv Primary Industries

v Other

4 Lab on a chip

i Bio-medical

ii Communication

iii Environment

iv Primary Industries

v Other

5 Electrical

i Bio-medical

ii Communication

iii Environment

iv Primary Industries

v Other

6 Other

i Bio-medical

ii Communication

iii Environment

iv Primary Industries

v Other

7 Impact or effect of microfabrication

i Global interaction

- ii Business
- iii No effect
- iv Disruptive vs. incremental

- International influences
- Efficiency
- International
  1. Trends
  2. Markets
  3. Difficulty
  4. Collaborating internationally
  5. Influences of Technology
- Awareness of involvement
  1. Unaware that they do microfabrication
  2. Aware that they do some microfabrication
  3. Only does microfabrication
  4. Does not do microfabrication
  5. Indirectly involved with microfabrication
- Industry Future
  1. Uncertain
  2. Positive outlook
  3. More collaboration
  4. Negative outlook
  5. Move away from primary industry
  6. Incorporate into primary industry
  7. Increase in manufacturing abilities

- Strengths
  - Specialists/ specialization
  - Mobility/Adaptability
  - Facilities
  - Research sector
  - Innovation
  - Improvization
  - None
  - Communication/Proximity
  - Collaborative atmosphere
- Weaknesses
  - Government regulations
    1. Health and safety
    2. Customs/importing and exporting
    3. Environment
  - Size/ scale
    1. Size of country
    2. Scale of production
  - Funding
    1. In company
    2. Due to government
    3. Competition for funding
  - Facilities/Equipment
  - Industry Existence/Visibility
    1. Lack of complete industry
    2. Public visibility

        3. Underestimated/not taken seriously
        4. Global visibility
    - Lack of communication
        1. Between sectors
        2. Within sectors
        3. With the rest of the world
    - Global Competition
        1. Against China
        2. Against other countries
    - Need for immediate globalization/ no market in NZ
    - Distance
        1. Between New Zealand facilities
        2. From other countries
    - Lack of People
        1. Skilled labor
        2. Specialists
    - Lack of Supply/ Resources
- Education
    - Degrees
        1. Electrical Engineering
        2. Mechanical Engineering
        3. Physics
        4. Chemistry
        5. Other/not specified
    - Jobs in New Zealand
        1. Family/significant other

2. Home
3. The environment
4. Culture

- Jobs outside of New Zealand
  1. No jobs
  2. Poor facilities
  3. Not competitive globally
  4. From a different country
  5. Family/significant other
  6. Desire to travel

- Objective 2
  - Willingness
    - Conditions to Join
      1. Mediator
      2. Common Goal
      3. External Funding
      4. All parties equally represented
      5. Applicable to Personal Work
    - Not interested
      1. Academia
      2. Think it cannot work
    - Interested
      1. Benefits to organization
      2. Benefits to New Zealand
      3. Benefits to all organizations
      4. Skeptical of success

5. Decreases nationally competition
6. Personal gain separate from organizational gain
7. Trading staff

- Barriers
    - Funding for Cluster
    - Common Vision
        1. Between sectors
        2. For the cluster as a whole
    - Internal Competition
    - Relevancy methods
        1. Reports
        2. Academic journals
        3. Conferences
        4. Trading staff
        5. Not enough time to stay up to date
        6. Clusters/relationships with other organizations
    - Lack of Communication
        1. Between sectors
        2. Within sectors
    - Awareness of industry
        1. Very aware
            - i. Research/Universities
            - ii. Manufacturers
            - iii. Suppliers
        2. Partially aware
            - i. Research/Universities

ii Manufacturers

iii Suppliers

3 Not aware

i Research/Universities

ii Manufacturers

iii Suppliers

- Growth of Company

1 Staying the same

2 Growing

3 Declining

- Knowledge of Clusters

- Knowledge of Clusters

1 Current clusters

2 Clusters, what they are/have been involved in

3 Little to no knowledge

4 Familiar with just concept

- Objective 3

- Environmental concerns

- Concerns to environment

1 Heavy metals

2 Nanotechnology

3 Solvents

4 Chemicals

5 Other

6 Hazardous waste handled properly

- No concerns to environment

1. Too small a scale to produce harm
2. Chemicals properly handled
3. Nothing harmful is produced at all

- New Zealand Culture and Society
  - Maori
    1. Ability to adapt
    2. Open to technology
    3. Conservative views
    4. Economic growth
    5. Primary industry
    6. Education/involvement
    7. Cultural conflicts
    8. Exposure to S.T.E.M.
    9. Clusters
  - Open to the idea of clusters
  - Openness to and Awareness of Technology and Microfabrication
    1. Openness
    2. Awareness
  - Primary industry
  - Ease of life
  - Change similar to global change

Appendix C: Other Organizations

Contact Attempted

- MSL
- Living Cell Technologies
- Aeroqual Limited
- Kahne Limited
- Pictor Limited
- Titanium Solutions Limited
- Koti Technologies Limited
- Mars Bioimaging limited
- Perry Engineering
- Adinstruments Limited
- Precision Microcircuits
- Smart Sensing and Intelligent Systems
- Veritaxa Limited
- Goodnature Limited
- Tekron International Limited

Contact not attempted

- Product Accelerator
- Helix Industries
- ASL
- Kiwinet

- Times-7 Holdings Limited
- Magritek
- ikeGPS Limited
- Institute of Professional Engineers NZ
- FutureIn Tech
- Triontech
- CSP group
- MBIE
- Polymer Electronics Research Centre
- SGS group
- Robbinson Institute
- Kode Biotech
- University of Otago

Appendix D: Transcripts

Interviewee: Alan Coulson

Interviewer: Rachel Ooyama-Searls

Organization: Callaghan Innovation

Location: Gracefield

Date and Time: 1/28/2016 9:30:00

Rachel: Can you state your name for our records please?

Alan: Alan Coulson

R: And the name of your company?

A: Callaghan Innovation.

R: Would you like to remain anonymous?

A: No.

R: Which part of the microfabrication industry would you say you are personally involved in? Supplier, manufacturer, research, or student?

A: Research.

R: Which part of the microfabrication industry would you say your organization is involved in? Again, the same four options.

A: Primary research.

R: Can you state your job title please?

A: I'm group manager for sensing and automation, which includes microfabrication.

R: In your own words, could you give us a job description?

A: It's managing a group of researchers, through to steering their research strategy, also the commercialization strategy of their capability and helping them to work with New Zealand businesses to transfer their technology, meeting New Zealand business' innovation needs.

R: What does the word microfabrication mean to you?

A: The first thing it means is a lot of money, because we spend a lot of money establishing and maintaining plant and equipment over the years, and also developing capability of new people and also equipment to be able to use those facilities. But obviously it's a technology of high potential future benefit to New Zealand. It's an area where good researchers can really push boundaries of what's possible and therefore can really help drive business opportunities. So, backed up by the amount of money we put into it, the potential for creating more money in the future is even bigger, we hope, it's worthwhile.

R: How does microfabrication play a role in your organization?

A: So, we really have a couple of roles, one of which is a research provider, we do provide those services and facilities which are accessed by New Zealand businesses to meet their microfabrication needs. To do that, we spend a lot of money in developing our capability, which is both plant, equipment, and people, and also because it's an embryonic industry in New Zealand compared to other bigger Western economies, we have a role in really trying to promote and seed the industry in New Zealand, so we're reasonably proactive in trying to cluster groups of companies around microfabrication capabilities, introducing them to each other so that they can share some of their facilities and costs and also knowledge and also potentially help them share their go-to-market strategies, really to try and develop the whole microfabrication industry in New Zealand.

R: In your opinion, how has miniaturization changed technology in New Zealand?

A: So primarily, miniaturization in New Zealand is a consumer of microelectronics. Our role in developing technology and taking it to the world or even internal consumption is relatively minimal, so obviously we have the same benefits as any other nation that benefits from microfabrication miniaturization generally.

R: What do you imagine microfabrication in New Zealand to be like in the next 5-10 years?

A: It would be nice to see the little seeds that are currently germinating in a few little areas really taking root and growing and clustering around 2 or 3 companies that have potential to really grow into substantial companies. At the moment it's very much a cottage industry in New Zealand, either you've got companies who are, in New Zealand terms, reasonably substantial but only use microfabrication for a very small portion of their business needs and we've also got start-up companies or garage cottage industry companies that are based on microfabrication but they're really dealing with niche and very very small markets, so the opportunity is for us to really grow either the companies that are bigger, making microfabrication more of their core business and also to help grow those cottage industries, so that they can be bigger, have bigger reach, and perhaps move into larger niches than they are currently in. So that would be the successes in 5 years' time if we sort of see something like 10% compound growth in those kinds of businesses.

R: How do you see ongoing miniaturization affecting the future in the next 5-10 years?

A: So that's just kind of from my perspective as kind of a Moore's law progression, things will just get cheaper, smaller, more efficient. Again, it would be nice to think that New Zealand could play a role in leading some of that, realistically, probably not. Again, we'll probably just be playing the little niches, we'll be part of the global trend, so again, New Zealand's role primarily will be a consumer, but hopefully we can increase our rate of production and technology developer of the industry.

R: How do you think miniaturized technology impacts society in New Zealand? If at all?

A: Again, as a consumer, everybody loves having smaller phones that are smarter and run for longer off the batteries. Things like Fitbit, go pros that weren't available 5 years ago, that's great from a consumer perspective. So it's really all of the convenience functionality that consumers experience.

R: What do you consider the strengths of the microfabrication industry to be here in New Zealand?

A: That's a really interesting question. At the moment it's pretty latent. As I've said, we've got a few little cottage industries and a few companies that use it as a small part of their business. Their strengths are really where companies like Precision Microcircuits that we work with have identified a niche and have exploited that niche to some extent. I guess you could say that Rakon, that's the quartz crystal producer, has a more of a global niche, then kind of on the periphery of microfabrication, cause it's not necessarily microfabrication technology, per se, but it's kind of a component that has some of the characteristics. So identifying niches and growing those niches is kind of the main strength and their success so far.

R: Then what do you see the weaknesses of the microfabrication industry in New Zealand to be?

A: So, that's the cottage industry trouble, the fact that they are in smaller niches and niches are always vulnerable to somebody. If the nation looks like it's going to expand, somebody big will come along and capture it and they'll be squeezed out then actually just collapse, in which case they don't have a business anymore, so the weakness is that they are, it is that cottage industry nature of it, so they are quite exposed, there isn't as much clustering as you probably need to get critical mass as an industry as a whole, so they I think, are the weaknesses.

R: How do you feel about collaboration with other organizations?

A: We're all for it. So, we think it's, for New Zealand certainly from the research provider perspective, there is a lot of microfabrication capability and facilities distributed out throughout New Zealand. At the moment it's not very well coordinated. For us to succeed as a nation, microfabrication we have to really provide a united, collaborative interface to New Zealand businesses, so they don't have to know, that for example, that we have a better ion etcher than Auckland university and have somebody to go to Auckland university, not being told about that we have a better facility, putting up with something second rate, and that's just an illustrative example, it’s not even factually correct so. But you kind of get the gist is that we’re very proactive in trying to pull together what we’ve called a national microfabrication cluster, so we think collaboration is absolutely key to the success of the industry, and certainly in the next 5 years.

R: What do you know about industry clusters and how do you see a cluster operating?

A: Industry clusters. Well industry clusters, they’re horses for courses, so each industry cluster will have its own characteristics, depending on the nature of the industry itself. So for example, we have an electronics cluster based in Christchurch, that kind of grew up around Tait electronics, which became, is the world’s second largest producer of public land mobile radio for security type applications. They’ve spawned a whole bunch of supply chain type electronics and then spin-off electronics within the Christchurch/Canterbury regions. And that’s been very specific to the electronics industry, it’s taken up some of the characteristics of electronics in that it started off being very supply chain focused as I say, around Tait so that the people who supplied Tait took their route to market and distributed things. Microfabrication is likely to take a different type of cluster structure I would imagine. I don’t imagine it starting off around a specific large company and then spinning off a supply chain, I see the opportunity as probably more of a kind of an organic thing where different cottage industries around different niches can collaboratively give more by presenting, I guess, more packaged offerings, sharing distribution strategies, those kinds of things and possibly growing the whole cluster at the same time, rather than single core focus that has spillover.

R: How aware are you of the microfabrication facilities in New Zealand?

A: Organizationally hopefully we know better than anybody, because we’re the one that’s trying to pull it all together. Personally I’m as aware as my latest reading of the information that’s my own on average.

R: How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication field? And why, or why not?

A: We’re trying to actively lead that process, so yes, we’re extremely willing.

R: Switching gears here. Are there any environmental concerns with microfabrication that you know of? And if so, what are they & how are they dealt with?

A: Ah yeah, obviously microfabrication produces some pretty nasty chemicals but at the scales that we work at, so long as we have robust health and safety practices and just normal laboratory operating practices that’s very well managed and easy to deal with. As far as to the best of my knowledge, and I’m personally liable for any accidents or toxic emissions, to the best of my knowledge it’s very well handled.

R: What types of government regulations affect your work?

A: Yeah, so that would primarily be health and safety regulations, which for us is common sense, so it's not so much that it doesn't so much become a barrier as a guideline as to what our best practice should be.

R: What is your current approach to stay relevant in the rapidly expanding field of microfabrication?

A: So, I guess we have some unique facilities and equipment. Our approach there is to maintain the currency of that equipment by continually refreshing it as we can. By international standards, we're extremely budget constrained, so it's really trying to get the most out of very modest amounts of funding in terms of the facilities and similarly with our human capability so our key researchers, they try and stay relevant by doing investigator led research in terms of developing their personal capabilities in niche areas that they see as benefit for New Zealand and again it's trying to spend that very small amount of money as judiciously as possible.

R: Is your organization looking to hire more staff?

A: No.

R: What factors make it difficult to compete in a global market?

A: So, for New Zealand, we are very small, and we're very distant, so geography is a barrier and scale is a barrier, but that simply means that we just need to be targeted and niche in our approach so to be able to identify the right niche is identifying how best to develop the value the distribution chains that people within those geographic industries can use.

R: What are the main and potential applications of your work?

A: I guess our work is focused on kind of sensing applications for health and agritech, sensing technologies for health and agritech type applications, but very much driven by needs of industry that we are working with. But that's kind of the general thrust for capability of our work.

R: How much money, if you know, does your organization spend yearly on R&D?

A: [redacted]

R: And then, how much would you say your organization spends yearly on microfabrication in particular for R&D? You can give a percentage, or an actual number.

A: [redacted]

R: How many people does your organization have on staff for microfabrication?

A: Specifically for microfabrication, 3 or 4, depending on how you count.

R: How many do you have total on staff?

A: In research, it's 200.

R: Do you have any additional comments you'd like to add as we're coming to the end of our interview.

A: I think you've covered a pretty wide amount already.

Interviewee: Andrew Best

Interviewer: Rachel Ooyama-Searls, William Boyd

Organization: Callaghan Innovation

Location: Gracefield

Date and Time: 1/14/2016 14:30:00

Will: So, which part of the industry are you personally involved in? This can be supplier, manufacturing, research, or education?

Andrew: So, I am involved in microfabrication research.

W: What part of the industry is your organization involved in, given the same options?

A: The organization that I belong to is charged with helping high-manufacturing within New Zealand. Advanced manufacturing

Rachel: What is your job title?

A: I am a microfabrication engineer.

R: What is your job description?

A: To, I to take care of the microfabrication facility, to make sure that it's operational for the scientists that make use of the facility as well as do projects, research, or make small things.

R: How does microfabrication play a role in your organization?

A: It is quite an important role in the organization. A lot of research areas require small things to be made. It could be something from photonics through to ultrasonics to nano-electronics, quantum electronics.

R: Which of the following technologies do you see having a potential benefit to your field: laser micro-machining, high-resolution 3D printing, electrically-conductive 3D printing, energy harvesters, micro-sensors, or other?

A: Other, and all of the above. Microfabrication, times change, there's going to be a new thing that's needed in the future. Anything small, we will have to make it, or research how to make it.

R: Which of the following techniques do you see having the potential to benefit your field: micro-lithography, thin films, doping, etching, bonding, polishing, photo mask, micro-molding, and other?

A: Again, this is a similar question and the response is all of the above. Polishing is perhaps one of things I wouldn't have necessarily because it is messy.

R: What are the main and potential applications to your work?

A: I am sort of not really focusing on that. It's more small, client driven, so, I am currently working on ultrasonic transducers. I am investigating biological sensors, micro-fluidics is still there, whatever is still in demand.

R: How has miniaturization changed technology in New Zealand?

A: We all use it. And I think the public is coming more and more aware that things need to become smaller to be better.

R: How do you imagine microfabrication in New Zealand to be in 5-10 years?

A: That is a good question. I guess part of this project that you are doing will help answer those questions. If it is perceived that there needs to be more money put into microfabrication and it could change the future. If it is the opposite, it could change the future as well.

R: How do you see ongoing miniaturization affecting the future in 5-10 years?

A: I guess, I do have a concern about privacy being, will be more monitored. I can microfabrication sort of intruding some of that. It is one area of concern. Obviously, there are benefits as well.

R: How do you think the microfabrication industry impacts society in New Zealand?

A: It impacts society. I think that the microfabrication industry is quite small in New Zealand so its impact is quite small, but I think it has potential to change that, especially when we can help out on something like the agricultural sector. What was the question again?

R: How do you think the microfabrication industry impacts society in New Zealand? Also, sort of along those lines the culture, the technology culture in New Zealand.

A: I don't think I have any more to say

R: What are the strengths of the microfabrication industry?

A: Because it is so small, it does have the ability to move quickly. So it can adapt to demand in different areas, and therefore I guess because it is small, it also has ways of, quite highly regarded engineers.

R: What are the weaknesses of the microfabrication industry?

A: It is too small. It probably doesn't have the facilities that it ought to. The industry demand for microfabrication is not really there. New Zealand is very much primary industry- focused. Secondary industry is not so high-tech. The amount of high-tech and manufacturing requires microfabrication is quite small.

R: What is your current approach to stay relevant in a rapidly expanding field, like microfabrication?

A: Reading papers, to being aware of developments. So, yeah, it is a personally problem as well. And I guess communicating with others, and knowing they have been developing and researching.

R: What do you know about industry clusters?

A: We would like one to start in microfabrication. Yeah, Callaghan Innovation is supportive of clusters and have tried to start a cluster here in New Zealand. It obviously requires others.

R: How aware are you of the microfabrication facilities here in New Zealand?

A: I have visited most of them. So, yeah.

R: How willing would you be to join a cluster initiative for microfabrication?

A: I think very willing.

R: How do you think your organization would benefit from being in a cluster?

A: Our organization because it's to help with advanced manufacturing would benefit by helping other companies with microfabrication. We are here to benefit others, not necessarily to benefit ourselves.

R: What types of government regulations affect your work?

A: The Emissions Trading Scheme does restrict certain processes. The emissions of greenhouse gases. So, we don't go down that road. Misuse of Drugs Act affects us somewhat even though we can't get licenses to use certain solvents. It is a costly burden.

R: You feel that this makes you less competitive with other countries maybe? Like for the New Zealand industry. Your regulations versus maybe China's regulations.

A: Obviously China. I think the labor cost is probably the main concerning thing. Yeah, I don't see the regulations being too restrictive. There are other things that are more effective.

R: What other companies or research groups in New Zealand have interest in microfabrication that you know of. Do you know who we could contact? And what are your connections to those people?

A: I can give you a list.

R: What are the specific chemicals and processes for the environmental concerns that you talked about with the agent or the laws?

A: The chemical the solvent we cannot use is GBL which is a precursor for phantasy. New Zealand has the tightest regulations in the world, whereas most of our competitors don't have restrictions. I was told that it comes out of China like water

John: And how does this negatively impact what you can do?

A: It is not a major impact. We work our way around it. The other one is, when it comes to using these greenhouse gases is, the fluorocarbons. We don't have a dry-etching process and one of the reasons is because we don't have, it's forbidden to get a hold of the gases.

R: Does that negatively impact what you do here? Or like your potential to do here is?

A: I think if we had a process that required it, it would be costly to deal with.

J: So, I am gathering that this stage right now you do not have a process that is completely dependent on the dry-etching.

R: But if had something that needed that it would be very difficult, but you could adapt to

A: It would be a hurdle that we would have to work through.

Interviewee: Andrew Dawson

Interviewer: Rachel Ooyama-Searls

Organization: Callaghan Innovation

Location: Gracefield

Date and Time: 1/18/2016 11:30:00

Rachel: Just for our records, could you say your name?

Andrew: Andrew Dawson.

R: Would you like to remain anonymous?

A: It doesn't matter, its okay.

R: So, a little introductory stuff. What part of the microfabrication industry are you personally involved in: supplier, manufacturer, research, or student?

A: Given my role - so to give you a bit of background that might help and you can determine it for me. So essentially, I'd say probably supplier actually because my role at Callaghan here is to source R&D capability for companies outside their own organization. So I look after sensing and automation companies. So if we get a company that says, "Look, we've got a sensor that we think we can fabricate or its novel and we want to do it here in New Zealand," then I could source microfabrication capabilities from the universities, Crown Research Organizations, other companies. So if it was something like a lab on a chip then for example, we would do it here in our microfabrication lab with these guys. So if you go through it, then you'd say yeah, research and supplier, I would say.

R: The next question is: Which part of the microfabrication industry is your organization involved with?

A: Research.

R: What is your job title?

A: National Network Manager, Sensing and Automation.

R: In your own words, can you give us a job description?

A: I guess I kind of did. But the only thing I'd also add to that is as part of that role, it's not just about supplying R&D capability to companies in New Zealand, it's also about creating new partnerships between companies. So that could be company to company, it could be company to university research organization, sometimes it can also be company to government because we have a number of R&D grant schemes that we offer through Callaghan and expose them to new partners. And I guess one of the other things is looking out for trends amongst companies, so an example could be like if there was enough demand, then we'd start looking at the possibility of starting a microfabrication cluster, which is what you guys are sort of working on at the moment.

R: So what does the word microfabrication mean to you?

A: It means fabricating devices or systems at the - well you'd say micrometer scale, but nowadays I would consider that it would also sort of encompass the nanometer scale as well. It means using techniques like etching, whether it be wet etching or dry etching. It could be using methods like DRIE, it could mean using (...) to create transducer sensors, whatever. So thin film devices, anything that - also I guess it doesn't necessarily require a cleanroom, but sometimes you'll see that, microfabrication with cleanrooms, because small devices we want to avoid contamination and so forth.

Tyler: You said DRIE? What is that?

A: Well, RIE, so just Reactive Ion Etching.

R: How does microfabrication play a role in your organization?

A: So one of the key roles it plays is supplying New Zealand business with novel and new ways of fabricating devices for them. It also means realizing their concepts and ideas physically. So as an example, we have companies that we source that we then pass on to the microfabrication team here at Callaghan. And they can then either recommend or say, "look, you can either buy this off the shelf or we can prototype this for you and see that we can actually realize the idea, that it's actually physically possible." Or they'll go ahead and they'll know they can make it and they'll do it under contract with a company and we've got quite a few decent pieces of equipment compared to other microfabrication facilities in New Zealand. So yeah, we're a pretty good starting point for New Zealand companies who are looking to undertake microfabrication ideas or prototypes.

R: In your opinion, how has miniaturization changed technology in New Zealand?

A: That's an interesting one because there are companies within New Zealand that are using new devices that are sourced from overseas to create new concepts. So as an example, we've just come back from CES and one of the companies that we took over there is called VXSport and they make high end GPS tracking devices for athletes targeting college sport and pro sport. And they certainly wouldn't be able to realize those devices without miniaturization because these guys make devices for the All Blacks, do you know who the All Blacks are? So they've won two World Cups now with using that technology and they've basically said, the All Blacks have actually said that we wouldn't use anything else. So (...) have come to them and so forth and they've offered to give their solution to them for free and the All Blacks said, "look, we like VX's technology. It's small, it's portable, it works well, it stands up to the rugged environment that is rugby." So yeah, that is one example. We've got another couple of companies who I probably won't mention just because of what they're developing, but through the use of microfabrication sourced through Callaghan, they've been able to realize their device into a portable, compact package that is now appealing to international companies and suppliers of that technology. So without miniaturization, they wouldn't be interested.

R: So what do you imagine microfabrication in New Zealand to be like in 5-10 years?

A: What would I imagine or what would I like?

R: Both.

A: Okay, so what I would like to see is New Zealand cooperating as a single microfabrication group. What I would also like to see is not doubling up of specialized equipment because we do see that quite often, is we see duplication of a mediocre device as opposed to New Zealand having a one-off, really cool gigahertz NMR system. Instead, we have multiple ones that operate at lower frequencies, for example. And what I'd like to see is that we've figured out the whole issue of how people can use that space affordably and I'd like to see us producing some really cool lab on a chip solutions. New Zealand's become a producer of niche transducers and sensors. We're already starting to do that with one or two companies where their products are being developed for an overseas market that can't be sourced anywhere else. It's quite niche, but at the same time it's quite profitable so if we could have more of those things taking place, that would be really, really cool as well. How I imagine it to look...maybe in 5-10 years it's not quite at that point, but I imagine it being more coordinated and having an actual proper, official network established and working really well together, efficiently as well. Because sometimes when you set up these networks there's always issues around efficiency in meetings and people's time.

R: So how do you see ongoing miniaturization affecting the future in 5-10 years? I know we talked about the rugby a little but...

A: So based on what I've seen and the way things are trending, fitness and health seem to be a really hot topic. And the other one I can see becoming more and more important is telemedicine because that's pretty pertinent knowledge in New Zealand but also other countries where the cost of healthcare is rising, people demand - it's an interesting thing because the medical profession is constantly developing, so we're always bringing out new bits of technology that we as citizens want. However, because we have to purchase new equipment, that puts more of a toll on our healthcare system and we end up paying more. So being able to monitor yourself on a daily basis using miniaturized, small devices that you can't see that don't interfere with your daily life or activity, is something that's going to be really, really important. And we're seeing a lot of companies now that are sort of jumping on that bandwagon and as a result I think you're going to see - we're seeing new standards now being developed. So electronic standards to cope for a huge increase in the number of sensors. You've seen a lot of new wireless communication, hardware being developed. So yeah, I see personalized healthcare as being a big one, but also that could be the same in aggrotech as well.

R: How do you think the microfabrication industry impacts society in New Zealand, if at all?

A: At this stage, it's difficult to comment. I mean, now or in the future?

R: Now. So even the idea of miniaturized things or technology, high tech.

A: So I guess it affects society in a number of ways. You look at mobile phones, for example. You can't really go anywhere without seeing sensing technology. I mean, you're seeing UAVs, you're seeing automobiles, you're seeing mobile phones, you've got medical devices like we spoke about. Yeah, I think it affects New Zealand in a big way and I think it's the same globally and I think it's only going to get more and more in the future. I mean, you've got connected homes, smart homes. Yeah, so I think it's pretty big, to be honest. You can't really have technology these days without miniaturization. TVs for example, you can't have flat panels without small electronics, you know, LCD screens and things like that. So yeah, I think it's a big thing.

Will: What do you think the level of awareness of microfabrication is with the residents of New Zealand at the time?

A: The awareness of microfabrication. I think it's pretty limited. I don't think people realize just how much microfabrication and miniaturization affects their daily lives. And it's not until you actually start talking to people and make them realize what's involved, for example, in making a device like this. *holds up remote control* Something trivial like that. So I would say, in short, not much to be honest. I think New Zealand's focused a lot of times on primary industry which I'm sure you guys may be aware of. We're obviously a big producer of agricultural products, so a lot of our economy is focused around that and maybe design and aspects like that. But in terms of electronics and so forth we're quite small. I mean, people know what they're using and they know that it's small, but they're not aware of what actually goes on internally. That's my opinion anyway.

R: In your opinion, what are the strengths of the microfabrication industry in New Zealand?

A: I think part of our strength is being small. So what I mean by that is if we see a new trend that comes out or we see that something's going to have a big impact, we can be quite mobile in terms of what we develop and what we focus on. So for example, if we could see that energy harvesting was going to be a big hot topic or something like that, then we could mobilize ourselves to be specialist suppliers or manufacturers of new MEMS devices because often the case is we have - I've been overseas and you travel to materials labs, what you actually find is the equipment that we have is actually not too bad compared to international standards, and even our research capability. But just given we don't have the same numbers or scale that those labs have or the researchers, I think we have to be more selective and focus on particular areas of our strengths. Or I guess pick a topic, is the other thing, and go with it, because we see other countries do that. I'm just trying to think...you think countries like Sweden or Norway, for example, they're very successful and they have taken their economy and they've shifted it toward high value manufacturing. And that's what I think we need to do and that's why I say our small size is a strength. We also do have a really strong research component. So we've got some really key strong researchers who want to stay in New Zealand and do their research in New Zealand. So if we can have them working together, we'll create an environment for them to be able to collaborate more easily and have the funds available for them to do that research, then that would be really good as well. Yeah, and we've also got some really cool and novel companies in New Zealand and part of the problem there is they may have had a bad experience with research providers in the past and they're not necessarily aware of the research capability that's available to them. So if we could help break down those barriers by having, I guess, a microfabrication network that communicates and works well together, then that would go along well. So I think New Zealand's innovation system is an advantage to us as well, but it just needs better connecting. That's sort of our role, to improve that.

R: So what do you think the weaknesses of the microfabrication industry are in New Zealand?

A: Weaknesses would be - lack of communication is often a big hurdle, but that's not really unique to New Zealand. I think that's probably at a global scale, but you see that often. People always try and do things on their own and that also sort of comes down to our competitive research funding system. That doesn't help. And it's the same with companies as well. It's sort of like this mentality that we can do it on our own and when we look overseas that tends to be less so. People tend to be more - well that's not necessarily true, but I guess the thing is in New Zealand, again because we're small, we need to be more smarter that the enemy isn't the ones internally. Not the enemy, but the competitors are the ones overseas, not us internally, and if we combine our resources we'd be far more competitive internationally. And I guess the other thing I would say is lack of resource in some cases. It's not always capital, but also in terms of just researchers, research time or staff. We've only got limited capability in New Zealand sometimes for scale, which is an issue.

R: What do you know about industry clusters?

A: I know that sometimes they work and more often they don't, because so often they start off with a hiss and a roar, so everyone's full of enthusiasm, but I don't think people are quite clear from the beginning - if you're not clear from the beginning on what you want to achieve through that cluster, then it will quickly lose momentum. And again, sometimes they're not adequately resourced and that becomes a problem. But we do have some successful ones. I shouldn't talk about the negatives because when they do work, they work really, really well. And what you find generally is that early on you quickly find those who are committed and those who aren't. We've got one now in New Zealand, it's quite small but we call it the New Zealand Telematics Alliance. And that's a group of companies that are forming together in terms of developing new technology for telematics and tracks and automobiles. So being able to track them and providing information to the company. So there were a number of companies in New Zealand who were competing for that and then realized that they were far better off working together and far more competitive now overseas as a result of it. And I'm also working with one on herbal technology at the moment, because we've got some really cool herbal tech companies in New Zealand, and what we've found is through the cluster, that some of the more well established companies have said to the smaller ones, "you're manufacturing this for 150 dollars US a unit, but in actual fact, we could knock a zero off that through our connections in China and we can manufacture that for 15 to 20 dollars, tops. And so massively increase your bottom line," and yeah. It's been really, really cool. Also through that group, we've had new partnerships being developed in terms of research partnerships and new technology being developed. Even though they're a slightly different business, the technology is relevant to both of them, so yeah I know a reasonable amount about them. I could talk about them all day, but I won't.

R: How aware are you of the microfabrication facilities in New Zealand?

A: Pretty aware. I know Auckland's, I know Canterbury's, I know Wellington's (so Victoria University's), I know Callaghan's. I know a little bit about Massey; they've got some equipment, but I guess you're talking about cleanrooms here specifically? There's also companies like Rakon, they've got them. Some other companies who try to fly under the radar a little bit more about their equipment. We actually do have some pretty specialized equipment throughout New Zealand, but it's the universities that are the most accessible in terms of that.

R: How willing would you be to join a cluster initiative for microfabrication? And why or why not?

A: I'd be keen to join it provided that the interest from industry is there because ultimately our organization is about supporting New Zealand's R&D and high value manufacturing businesses. So if there's benefit to them by establishing a cluster, then absolutely. But I wouldn't necessarily be keen to support it if it was only the academic and more research institutions that were forming it. So if it were only going to consist of universities and CRIs, that's fine; I'd be supportive of it, but not keen to necessarily promote it or spend a lot of time on it because again it's about adding value to New Zealand's businesses. But if they could demonstrate that by them forming a cluster together that they were able to better serve New Zealand's companies and develop new technologies more efficiently and faster and I guess higher end devices, then yeah that would be fine. It comes down to the value proposition for New Zealand's R&D businesses.

R: So are there any environmental concerns with microfabrication? And if there are, can you go into specifics?

A: I guess there are concerns sometimes depending on what sort of solutions you're using. If you're doing a dicing process, they don't have any concerns. But if you're using a lot of what we spoke about earlier, which is the DRIE, you can produce some nasty gasses like SF6 and so forth which are hazardous to the environment, then yeah I'm not too keen on that. But there are a number of alternatives to most types of processes, so if we can use those instead, I don't have an issue with that.

R: So what types of government regulations affect your work?

A: I guess it's indirectly...there was one recently where we had a company - so there were a couple of companies that were having to source an alternative...I'm just trying to think of what was used. I think it was used for making thin films devices. Because of health regulation within New Zealand preventing the use of this other solvent, that's right! The one that they wanted to use was banned in New Zealand because the chemical was used as a precursor to making methamphetamine? Fantasy? It affects us because we've got a big company here called Glycosin and as a result, I think Rakon were also affected, we were affected, and a couple of others. And what it means is that we have to buy expensive alternatives that are, yeah, much more expensive to source and it could be a lot cheaper if we could use the alternative. We've sort of started to go through the process of reducing that or preventing that regulation from applying to us and affecting some of the companies.

R: How do international trends shape the future of New Zealand microfabrication?

A: Quite significantly because we have to be aware of the new technology, or our companies have to be in order to be competitive because if we're not incorporating the new techniques of microfabrication, we're going to be operating at a different scale, which means that international competitors are going to be able to say, "oh look, we can change the properties or make this device smarter or make it operate at a high resolution." Then we're never going to be able to and, as a result, we're going to reduce our competitiveness in the market. So absolutely, New Zealand needs to be aware of all the trends and try and keep ourselves up to date as possible in terms of our equipment. That means companies and also government laboratories, universities, so totally affected by international trends, yeah.

R: Is your company looking to hire more staff?

A: Essentially our company would operate if the demand is there and if New Zealand companies could demonstrate that there was a real need for more microfabrication in New Zealand, then absolutely we would. We will respond to whatever industry tells us, really. But, being Callaghan, we would position ourselves in more of a niche space serving any area of which companies and other institutions aren't fulfilling, basically. That's what we should be doing and that's within our mandate and that's what I imagine we would do if the need arose, sure.

R: What products does your company provide for the microfabrication industry?

A: Well, we provide prototypes of a range of products. One of our strengths going forward I think is going to be lab on a chip devices. We also provide transducers, so piezoelectric transducers and devices. We've made 2D arrays in the past; we've made single element devices. Andrea and Andrew and Mike's team will be able to advise on other stuff that we've made. I'm just trying to think of other things. And in the past, we've also done microelectronic devices as well. But we sort of stopped that a number of years ago because we just couldn't compete with large scale manufacturers like Intel and the semiconductor industry and so forth. Yeah, so thick film, we do some thick film devices as well; we've done angular arrays as well. And we've also had some companies use our facility, our cleanroom facility. So HTS Platform, Rakon, Spark Transducers.

R: What country do you do the most business with?

A: It's difficult to say, actually. In terms of microfabrication or…?

R: Yes.

A: In terms of microfabrication. Perhaps the US. That's a good question.

R: New Zealand is also an option.

A: Oh, okay. For me, so New Zealand is probably primarily. You're talking about in my role essentially...then yeah definitely New Zealand's the one we deal with the most, yes. But it would be followed by the US probably, and Australia.

R: In your opinion, what factors make it difficult to compete in a global market?

A: I mean it shouldn't, but location is a big one. The difficulty in scaling can be quite difficult. You know, we don't have a lot of people to manufacture devices in New Zealand. Resource is another one, lack of resource. Because we may have a lot of new ideas coming through New Zealand, but if we don't have the financial capital to support it, then we have to look overseas and that immediately means we're competing with a lot of other people for investment. I certainly wouldn't say talent or education, although sometimes that can be an issue because, I mean this is talking at a little bit wider than microfabrication, but we've had companies that are growing at the rate of

50 staff a month and they just simply can't source it here within New Zealand so they have to look overseas. And in the case of microfabrication, it does come back to if we are operating in an industry which is not - so we really are targeting high value, low quantity manufacturing, but if we start developing products that are more low value but high volume, we don't have the ability to produce that here in New Zealand so we have to look overseas and we'd like to keep that in New Zealand. Yeah, then you run into issues around IP protection because you're starting to use contract manufacturers overseas where they can pull it apart, they can do all sorts of things and steal IP so that can be tricky in terms of competing.

R: And our last question is: What companies do you supply in New Zealand?

A: We essentially supply all businesses in terms of requiring product development or I guess an R&D component, primarily around high value manufacturing. But as I say, where possible we try and supply - but I guess again you're talking specifically around microfabrication? Because we always have to think broader than that, yeah. So I think the agricultural sector is one where we do quite a lot, but again we do high value manufacturing of specialized devices. So we do sensors, for example, for the automotive industry. In terms of aggrotech, we're looking at developing lab on a chip solutions for applications in the cultural space, so it could be looking at animal health. What else do we do? Yeah biosecurity as well, that's another one. And also for the medical industry as well, so healthcare, medical technology. Let me think for a second. Any others that I might have missed? That's quite a range there, anyway.

R: So do you have any additional comments you'd like to add?

A: I'm just trying to think. Not really, I think we've covered most of the things there.

R: Do you know of any other companies or research groups in New Zealand that would have an interest in microfabrication? And if you do, can you give us some contacts and your connections to those contacts?

A: I can, that's okay. I can go and have a look at some. I can't think of them offhand now.

R: Can we use your name in association with Callaghan Innovation?

A: Yes, that's fine.

R: Awesome. Thank you.

Interviewee: Atawhai Tibble

Interviewer: Rachel Ooyama-Searls

Organization: Finance Ministry

Location: Asteron

Date and Time: 1/22/2016 11:30:00

Rachel: For our records can you please state your name?

Atawhai: My name is Atawhai Tibble.

R: Can you say the name of your organization?

A: I work for the New Zealand Treasury. So you know the Finance Ministry. Government agency, so we give these guys the money.

R: Would you like to remain anonsymous?

A: No, I'm fine. I don't mind.

R: Alright. Which part of the microfabrication industry would you say you're personally involved in? Supplier, manufacturer, research, or student? This may not be applicable to you.

A: Not applicable. What is microfabrication?

R: Microfabrication- Well, we're actually going to ask you in your own words what microfabrication means to you but I guess we will skip that question. Microfabrication is the manufacture of devices on the micrometer to millimeter scale. Very tiny, compact, computer chips and things like that.

A: So what are the things they are using them for like right now?

R: Accelerometers in your phone, sensors in your computer mouse, sensors in your body, they could be used for-

A: On the watches? Not like in this one but.

R: Like in Fit Bits. Also you can have multiple sensors to measure blood pressure. Things like that to detect heart problems.

A: These aren't the ones that you inject into people are they?

R: They can be. It's called lab-on-a-chip. You can do analysis almost as if it was lab work just in this tiny tiny scale and get results and test proteins, that sort of thing. You can also use them to bring on-site situations like if you want to know heavy metal concentrations in water you don't have to take a sample back to a lab, you can bring a chip and do it there.

A: Alright, cool.

R: What is your job title?

A: I'm a Principal Advisor of the Maori Economy at the Treasury Department. So, it means a couple of things. So, the acceleration and settlements of treaty. The treaty settlements with the government. So that's where the original settlers and the indigenous people had agreements and the courts of the government have realized, "Oh, we stuffed up so we compensate you guys and get you on the right foot and you go and do your thing." So, that's been accelerated so that's one aspect of it. Another aspect is the government is trying to encourage a really pro-business environment and a pro-economic development environment on the primary sector side. You know, we are a big primary industry producing country and part of that is you got this injections of capital into the community, you've got a government trying to be much more business friendly and this possible synergies. So there's a team in here that Hami runs, I don't know if you met him, and he's the Maori economy team and he's trying to connect those dots between tribes and incorporations and farms that are owned by Maori people and New Zealand in general has a low productivity issue so the government in general is saying what can we do to help support businesses and farmers and companies kind of get more into producing more efficiently, more effectively, and I think this happens at the same time as innovation and technology is lifting the opportunity to do some really cool things. And with the lean startup approach, you know the whole tech, Silicon Valley kind of thing. It's how you rather than take the long route in the old days, you find smarter ways to do that. I think with the government, our job is to help connect people, connect the dots because businesses will typically be either siloed or focused in on doing their day-to-day, they may not see the opportunities, they may not be connecting. We have an R&D

sector here but it's obviously not as big as in the US and the crown, or the government, has quite a good effective coordination role. My role is in that space.

R: Gotcha.

A: Trying to help people join the dots.

R: How does microfabrication, or does microfabrication, play a role in your organization?

A: Not specifically. It mean, I know what it will be. It's exciting and it's the type of thing that- Again, if we can help connect the dots with people it will send teams of people over to those kind of trade shows or things over in the US or elsewhere in the world. If we can do that, it helps inspire farmers or researchers or business people to explore the unknown and have a go. I think that's the type of thing we should do, we should support.

R: How has, in your opinion, miniaturization changed technology in New Zealand?

A: Pass

R: How do you think miniaturization, so smaller technology, impacts society in New Zealand?

A: Just theoretically, anything that's more efficient, lower cost, helps the economy grow, helps improve people's wellbeing. You know, these kind of risks and tradeoffs in everything but in general. I think Fit Bits seem to be lifting and helping people monitor their progress. Those are good things. Cell phones, look at cell phones. People are walking around with a computer in their pocket. It's got more processing power than what took Apollo 13 to the moon. In your pocket! So, of course it's making a difference. I think the economic challenge is: is this really improving our productivity and I think there is some challenges around the world in terms of are we just getting more stuff? And being able to do stuff more low cost? Is it resulting in higher wages for people? There's a bit of a challenge there.

R: What do you think makes it hard to compete for high-tech industries globally for here in New Zealand?

A: I think that specialization and it has to be specialization and it has to be. I don't think distance is a big problem that it used to be. But it still is a problem because the whole notion of hubs and sitting around each other and working with each other, that's got to be a challenge for New Zealand. But I don't think it's the challenge it used to be. With Peter Jackson and what he's doing and Merimark and building those big pipelines that develop movies and you know. I think James

Cameron lives here now, he's making Avatar 2, 3, 4 here. So you know those challenges aren't as big as they used to be but they are still there. Distance is still an issue. And you want to be able to talk to the person who is doing the stuff as if they are next door. Although, that stuff does change. You know, WhatsApp or whatever it is. Skype or whatever. It does change things and I mean you see that kind of network working between India and stuff being outsourced. So I think at the end of the day, it's a mental thing plus a location thing. Maybe the mental thing is getting the right smart people around each other creating s***. Bouncing off each other. I think that's the thing. Where are the world experts? Are they in the US?

R: US, China, technology is always big in China. They can manufacture things very very cheaply.

A: But the brains still get sucked up to the US though eh?

R: Yea, Silicon Valley, a lot of innovation is definitely in the US. There is a small cluster in Massachusetts.

A: So what stuff do they specialize in? Because you will be

R: In Massachusetts we know that they specialize in high aspect ratio lithography which is a manufacturing technique from what I know and they specialize in that kind of thing where with Silicon Valley, it's technology in general. How do you feel about collaboration between other organizations? How does the government view it I guess? Collaboration between organizations.

A: I mean, I think ultimately it's the only way it's going to work. I'm not schooled up on the IP side of it you know but obviously the real value is not just in the IP but in the use of it to the consumer. I don't know that New Zealand has much choice but to collaborate more here. And that seems to be the model. So I think it's a. You can't not collaborate unless you've got a little monopoly going on.

R: What do you know about industry clusters and how do you see a cluster operating?

A: I've seen some, in broad terms, clusters operating here in terms of the whole collaboration aspect. That you know, if you can't do the whole thing yourself or if you've got an idea, if you can partner up or even just sit in the same room or same coffee shop or same lobby or be at the same after-dinner party or the same workspace, talking things through and talking things out and kind of working things out kind of differentiation, specialization, I can do this, you can do that, how do we bring that together, that's just smart. I know that New Zealand, this is what we gotta do when we take groups overseas as Callaghan does. The fact of the matter is that we don't have the R&D spend here. In the past, maybe this is a challenge, in the past, distance has forced people, and cost has forced people to make do with the things that they have. It's like the farming thing. You just make do with what you got and you've created an innovation without even knowing. You've just had to, you know. Create this thing because otherwise you couldn't plow the fields. So New Zealand has had a history of that. I just wonder though if things have changed so much in terms of technology and how you make things happen, bring things together, that's all a different space and it's less of the practical "I'm a toolmaker and I join this thing with that thing and then I can plow my field faster, three times what I used to." Now it's kind of nanotechnology and all these things, it's just a little bit different. So the principals are the same, what you might need to do through necessity being the mother of invention. You may be forced to create things because you have to make do with what you got. I think that the principals are there but maybe the game has changed a lot because technology now is about having that special technical expertise that we don't necessarily have here across a wide range of things. We may be way behind the 8-ball. I don't know but with microfabrication. I suppose it depends on the cost and the science and how much is well known or is fully understood or how much people in laboratories are just going for it and just crazy s***. Looking after the Chinese who are going to steal it or you know, Samsung versus Apple. You hear about those things all the time. Collaboration is important. Do we have the size here to, and the depth, our expertise, I suspect we won't but we will probably have areas we can focus and specialize in and maybe this work we can lean on. This is all quite technical.

R: It's not all technical but it

A: You guys are microfabrication is your thing?

R: So I guess my next question is more of a cultural question. Are there any direct cultural conflicts or even indirect cultural conflicts with Maori culture and high-tech industries or technology fields?

A: Cool, cool. This is what I am thinking, I'm thinking out loud so this is just a bit of a brain dump. There's a huge conservative element within Maori traditional culture that I think is quite strongly aligned with Christian ideas and ideals and, you know, you can get some quite conservative views about "Don't play around with God" stuff, you know. "That's God's domain." You can't do that and to a lesser degree, sometimes that gets involved when you inject things in you and you know, little things floating around and having a look and whatever. I would say that there are aspects within the culture that are quite conservative and they might say that goes against our values. But on the other side, all cultures are kind of, you know. They aren't just black and white or left and right or this, they are this and that and it's an- On the other side, you have lots of myths and legends and stories of people who came from the islands when they came here and how innovative and how they broke rules and they did things differently and they started off doing one thing one way when they are on the islands but they came here they threw it all away and did something else. So, innovation in that sense is part in parcel of a voyager's DNA. You come from one place, you go to another. It was hot there, it's cold here. You've got to change the way you eat, what you eat. You've got to change the rules, the way you dress, all those things. I think it's not a simple thing to say "Ah technology, it's against our culture" because we've adapted. Every time. At the same time, I'm acknowledging that there are people that will say "We don't do that! 75 years ago that's not how our old people did it." And lots of cultures are like that. Lots of people are like that but actually you look within your stories, you go actually human beings are innovators, we're adapters, we don't just stay in one place forever and ever and ever. We come from one place, we go to another. You train, you adapt, you innovate. And you create new technology, and you adopt new technology and I think I'm more sympathetic to that view.

R: Do you have any additional comments?

A: I'm interested in what you guys do. Like this whole microfabrication and where you guys think it's all heading. And what your special areas of expertise are. And just on that too, if you say really technical fancy thinking like you know, in the iPhones because then I'll get it.

Interviewee: Bart Ludbrook

Interviewer: Digital

Organization: MacDiarmid Institute, Victoria University of Wellington

Location: Digital

Date and Time: 2/1/2016 11:00:17

Question: What is your name?

Bart: Bart Ludbrook

Q: What is the name of your organization?

B: MacDiarmid Institute, Victoria University of Wellington

Q: Would you like to remain anonymous?

B: No

Q: Which part of the microfabrication industry are you personally involved in?

B: Research

Q: What part of the microfabrication industry is your organization involved in?

B: Research

Q: What is your job title?

B: Postdoctoral Fellow

Q: What is your job description?

B: I do research on nano-scale spintronic devices. We sputter-deposit thin magnetic multilayers and use micro (or nano)-fabrication processes to make devices.

Q: What does the word microfabrication mean to you?

B: In my area of research, it is essentially lithography (optical or electron-beam), used to pattern thin films into functional devices. Of course there is a broader definition including MEMS etc., but I am not familiar with that.

Q: How does microfabrication play a role in your organization?

B: MicroFab is used by a number of research groups at Victoria University. Groups are studying different materials, for different reasons, but the need to pattern the materials into devices to test them is universal. Access to cleanrooms and microfabrication processes is essential.

Q: How has miniaturization changed technology in New Zealand?

B: Same as everywhere else in the world. Better technology, smaller, faster, cheaper.

Q: What do you imagine microfabrication in New Zealand to be like in 5-10 years?

B: I hope there is a cohesive network of MF facilities that researchers and companies can access. Facilities would have the equipment and expertise required to help develop commercial ideas.

Q: How do you see ongoing miniaturization affecting the future in 5-10 years?

B: The miniaturization of transistors has obviously had a pretty strong impact on computing power and all the changes that has brought about. This trend will continue, along with all other electronic components.

Q: How do you think miniaturized technology impacts society in New Zealand?

B:

Q: What are the strengths of the microfabrication industry in New Zealand?

B: Good collaboration and sharing of facilities where network exists.

Q: What are the weaknesses of the microfabrication industry in New Zealand?

B: It's hard to get an overview of who is doing what, and what facilities might exist elsewhere. In particular with private industry.

It's small, and some equipment is not available.

Q: How do you feel about collaboration with other organizations?

B: It's usually positive for all parties.

Q: What do you know about industry clusters and how do you see a cluster operating?

B: Nothing. A good starting point would be an online network and occasional cluster meetings.

Q: How aware are you of the microfabrication facilities in New Zealand?

B: I'm aware of what is available in the universities, but I have no idea what exists in industry.

Q: How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication field? Why or why not?

B: Very. We could benefit from economies of scale.

Q: Are there any environmental concerns with microfabrication and if so, what are they and how are they dealt with?

B: Just the usual disposal of solvents, chemicals etc. Good lab design makes it much safer and easier to dispose of these things in an environmentally responsible way.

Q: What types of government regulations affect your work?

B: Some chemicals are not easily available.

Q: What is your current approach to stay relevant in this rapidly expanding field?

B: Read journal articles.

Q: Is your organization looking to hire more staff?

B: I don't know. Don't think so.

Q: What factors make it difficult to compete in a global market?

B: Equipment, and person power. We tend to have small groups working on projects.

Q: What are the main and potential applications of your work?

B: Spintronic devices. Spin-transfer torque RAM.

Q: How much money does your organization spend yearly on Research and Development?

B: I don't know.

Q: How much money does your organization spend yearly on microfabrication in particular?

B: I don't know.

Q: How many people does your organization have on staff?

B:

Q: How many people does your organization have on staff for microfabrication in particular?

B: At Victoria University, there is 1 research group of about 8 people that is focused on MF. There are approximately another 10 people who use these facilities.

Q: Do you have any additional comments?

B:

Q: Do you know of other companies or research groups in New Zealand that have interest in microfabrication? Who can we contact and what are your connections with these people?

B:

Interviewee: Ben O'Brien

Interviewer: William Boyd

Organization: Stretchsense Limited

Location: Auckland

Date and Time: 26/1/2016 14:00:00

Will: What is your name?

Ben: Ben O'Brien

W: What is the name of our organization?

B: Stretchsense Limited

W: Would you like to remain anonymous?

B: Ah, well I don't know yet because I don't know what you're going to ask me. So, can I answer that again at the end?

W: Yeah, that's perfect. Which part of the microfabrication industry are you personally involved in? This can be a supplier, a manufacturer, research, or education.

B: Ah, um. I don't know if I'd say we are really. We, we, make sensors for wearables. You said the definition was feature size of less than a millimeter. We do have the ability to manufacture down to about a millimeter, and academically, several years ago I worked on some technology that could make things that were smaller, but I would say we are not a microfab company in the sense of your definition just then. The layers, in our sensors, are 100 microns or smaller, so, in that sense there's microfab happening. I don't know if that counts?

W: Yup, yeah.

B: Okay, in that case, we are a manufacturer of sensor products.

W: Thank you. What is your job title?

B: CEO.

W: Can you give us a job description?

B: Of a CEO? So, I am a co-founder, I run the company, I answer to the board, I set strategic direction, vision mission for the company, I am responsible for making (…) the right staff, the right people around us, high-level sales contract negotiations, training. I am the boss. Except, to the board and the shareholders, they're my boss.

W: What does the word microfabrication mean to you?

B: Well, you just defined it as making things' features that are less than a millimeter. Yeah, I think that is probably a pretty good definition. It is just making small things I think. What changes a lot is a lot of boundaries break down between like chemistry, mechanical engineering, electrical engineering. A lot of these things get really mixed up, and so, I think microfab in that sense is getting a deep understanding of the underlying physics of what is happening and making sure that you cover all those multidisciplinary elements. Certainly for us, with our sensors, you know, you've got chemistry, you've got processing, you've got electronics, you've got software and getting all that to work together is important, so I'd say yeah, under a millimeter, that is how you define it, but it's that, the multidisciplinary, and the intertwining of everything. That is, you know you can't just have like a bean, right? That is what it means to me.

W: Thank you.

B: Or making small things.

W: How does microfabrication play a role in your organization?

B: So, I guess we will be, like I said before, our sensors are macroscopic objects. They are not micro in and of themselves, but they have layers that are less than 100 microns, possible even less than 50 microns. Quite small. There is a lot of surface chemistry mixing, forming of thin layers.

You have to do so with a lot of high-quality and reliability, but also over fairly large areas, so, that is how it plays a role.

W: Alright, thank you. How has miniaturization changed technology in New Zealand?

B: How has miniaturized changed technology? Well, I...economically, I think it has given us an opportunity to sell our products, which aren't just beef and, you know, milk, sheep, things like that. Trees. I think that the fact that you can pack a lot of economic value into a small form factor with intelligence. You know, we are a sensor company right, but it could be anything. It could be software, which is built on miniaturization, or it could be new consumer products, or whatever it is, medical devices, anything like that. The fact that now you can get a lot of technology, a lot of value out of, a lot of economic value to a consumer inside a small package means for New Zealand because we are remote, and we're isolated, it means that you can actually make money. Ah, very hard to make money selling cars or like heavy things, big things from New Zealand. Miniature or non-physical are very good goods for New Zealand actually being able to compete.

W: Alright. Thank you. What do you imagine microfabrication in New Zealand to be like in 5-10 years?

B: Well, you're going to write a report, and then they're going to establish a cluster…. I don't know. I don't know how much there is, to be honest. I think there's quite a bit of material science happening at an academic scale and there's definitely a few very high profile companies like Rakon. You must be talking to Rakon, right? You probably can't say because they probably said "yes, I want to be anonymous." You know, they do crystal oscillators...but I can't think of many, to be honest. I don't think there's a huge industry. Certainly academically there's lots of people who are working in this space. So what would it be like? I don't know, but what I'd like to see - it would be cool if there were some startups, it would be cool if there were some people actually launching technologies into the market. I think it's still very early stage though, I don't see a huge amount. But that could be my ignorance.

W: How do you see ongoing miniaturization affecting the future in 5-10 years?

B: For the world, or for New Zealand, or for what?

W: For New Zealand.

B: For New Zealand. Well again, like I said, I think it means that we can continue to be competitive, right? You've got the Internet of Things, you've got sensors going everywhere, you've got - that's driven by miniaturization, electronics. Electronics use a lot of power, more in analytics and the small form factors and local to the problem. Better sensor technologies like our company's working on. So clearly that's going to drive a huge number of potential applications. So definitely there's that in New Zealand. I don't know, I think we're going to get sensors everywhere. I think just trillions of sensors. There's people talking in like the ten trillion sensor vision; that'll happen sooner or later, so definitely that will affect things. I think for New Zealand industry specifically, it will affect our agriculture, I would imagine. It will affect - you know, you're going to sensors all over animals and trees and things. But I hope, like I say, I hope that we can move away from that stuff and actually just have some exports. But I don't know, I'm not and industry expert, I would say.

W: How do you think miniaturized technology impacts society in New Zealand?

B: Well again, the whole world has been impacted by it, right? You've got MEMS sensors in phones, you've got miniature electronics, you've got - just the whole electronics revolution has changed the world for everybody, that's how it affects. Again, specifically to New Zealand, I think it'll have the economic effect of allowing us to do things that aren't just chunks of meat and so on. Yeah I think that's...how will that affect society? It's a good point. That was your question, right? How would it affect society?

W: Yup.

B: So I think you're going to hopefully see less people employed on farms. I really sincerely hope that happens. I hope that we get more people employed in high technology. It's obviously going to benefit the university system. I hope it attracts venture capital money. I hope that we get spinouts. I hope that it just shifts the economic base slowly towards something that's more high tech. But that's more a hope, I think.

W: In your opinion, what are some of the strengths of the microfabrication industry in New Zealand?

B: I don't know if I can speak to the microfab industry, because like I said, I don't know many players. But I would say a general comment on New Zealand is that we're very good at doing complicated little niche things. That's something that we are good at. So not so good at building massive hierarchies that can create, you know, tens or hundreds of millions of phones or whatever it is that you want to produce, but very good at coming up with something difficult, complex, technical, and specialist that requires a lot of knowledge, very knowledge-type teams with flat structures working together. That's something that Kiwis are good at, and so I don't think you're going to see like a Nokia or you might. But you're more likely to see like whole massive, very high-profile cottage industries forming. That would be super cool if that were to happen. That's what Kiwis are good at, I think, the complicated weird stuff but not so much the mass production hierarchy type stuff. Does that make sense?

W: Yeah. So in addition to the massive industries or the companies, what are some of the other weaknesses of the microfabrication industry in New Zealand?

B: What are the weaknesses? There isn't one, really, I mean that I know of. I don't know of many companies - like I said, there's lots of academics which I think are doing fantastic work. I can think of a few companies, I mean, there's not a strong industry there. New Zealand is still transitioning away from this agricultural thing that's still a dominant sector of the economy. I think obviously a huge problem is access to markets. So we're a long way away from where we would sell such products, and as such, any company that sets up here, you have to be prepared to travel a lot. I go to the States once a month, which is grueling. A lot of flights. So that's definitely a weakness: access to markets.

W: How do you feel about collaboration with other organizations?

B: Collaboration works really well when someone's paying the bill. So for example, a customer or someone might come to you and say, "Hey, I have a project. I'd like you to do it. I'm prepared to pay this much." And you then get a bunch of organizations to work with you to deliver on that project. I've done that collaboration. It could be a grant, funding body, could be a customer. Someone wants something, they want to pay for it, and it requires multiple people to deliver...collaboration in that sense: very, very good. We've done it successfully many times. It's clear, you have contractual lines, "You do this, I do that, we do that together, we deliver this." Great. Collaboration in a "let's just get a bunch of people together and collaborate with no target," that I've seen a lot of and I don't think it works very well. I think you - what tends to happen, academically especially, is you get a project for people to collaborate on but no clear output and basically everyone just chops it up and then funds their own private projects that have limited overlap so it's not so much a collaboration [redacted] That's how I'd describe that. That is kind of two extremes, right? One extreme, you have a very targeted output, good for collaboration. Another extreme, and again these can both be academic or commercial, other extreme you have no targeted outcome, just sort of a general, vague theme. And I don't like that at all. The other form of collaboration that I am very pro is just swapping people. So I've seen that work extremely well. So a student from this lab just goes and sits in a different lab, or some person from this company goes and sits somewhere else just for the sole purpose of exchanging ideas, freshening up the idea gene pool. That, I think, works really well. Better in a situation where IP is not such a problem. So like academics is good, companies not so easy. But yeah, I think collaboration tends to work when there's a targeted, concrete, measurable deliverable output and someone paying for it. Because then, you know what success is. Not so good if it's just vague, "let's work together on this theme." I don't like that.

W: What do you know about industry clusters?

B: Not much, I'd be guessing. I would guess that it's where a government creates either incentives or space or facilities where a group of similar companies or academic institutions can get together and work on similar problems. I haven't really participated in an industry cluster before myself, though. So, not much.

W: How aware are you of the microfabrication facilities in New Zealand?

B: I think I'm fairly aware of the academic ones. So I know there's like a Photon Factory in Auckland. I know there's like a micro and nanotech facility down in Wellington at University of Victoria. I know there's the CHEMMAT department, kind of like the Photon Factory and stuff. But I know they do a lot of materials science like zinc oxide and stuff like that. So academically, I think there's a few big ones. I don't know if I've got them all. I'm unsure how aware I am, is my answer.

W: How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication field? And why or why not?

B: I'd be willing if there was a fairly tangible reason or outcome. Like I said, I don't believe in consortia for the sake of consortia. I find them political, I find them...I just haven't...nothing's ever really - maybe I'm being a bit harsh. I don't really see us committing to or getting value from something unless it's very, very clear what's involved. So it could well be, "hey, Stretchsense. You pay 50 thousand dollars, 20 other people also pay 50 thousand dollars, and then we get some equipment that has some incredible value to you that you couldn't get." Maybe, but I doubt it, because probably I'd just want to buy that equipment myself, get it on a loan or whatever if it was that critical. And then if it was that critical, I probably wouldn't want to share it, so I don't know. Yeah, I don't know. If there was a tax break, maybe. If there was a group of buildings and people said, "Hey, we'll put a whole bunch of similar companies in and around a physical location so that you have high bump factor with potential suppliers," yes. Good. But I'm not that warm on it. Also, all our customers are in the US and offshore and so that's where I want bumps to come from.

That being said, we do a lot of research with universities, but it's not part of clusters. I think we are part of a few consortia for various things, but it's more just like direct supporting, like the lab that we came from.

W: Are there any environmental concerns with microfabrication that you're aware of?

B: There's environmental concerns with everything. Things you can do wrong with microfab! You can create nasty stuff in the environment, could be just bad chemicals, right? The actual output could be dangerous. You could be using nasty chemicals in processing like chemical vapor deposition or what have you. Or like HF, right? What's that acid, HF I think? Yeah, hydrofluoric acid. That stuff just murders you if you get anywhere near it. So there's obviously nasty chemicals there which you have to worry about. Being in a clean tent sucks. It sounds all romantic and exotic when you first hear it and then you realize it's just wearing a crappy gown and mask, and it's sweaty and hot and painful and annoying. I don't like clean tents. Clearly you release nanoparticles into the environment. Who knows what they can interfere with and interact with? Probably breathing issues, who knows how they break down...yeah, I'd say there's lots of environmental issues.

W: What types of government regulations affect your work?

B: I hate customs. We ship stuff all around the world, right, and customs is just like this jail that randomly and arbitrarily takes stuff and sticks it in the jail. I don't want to pay duties, but I don't mind paying duties so if there's going to be a duty, fine. I can pay the duty. But the fact that the product will be held for an uncertain period of time by people who we don't know, have no control over, who have their own jurisdictions - like we sell to 22 countries now - I really hate that. So I'm all for free trade agreements if you can actually get one to stick, although they're probably not free trade anyway because so many tack-ons get added on it's not really. But customs, I don't like it at all. It's ridiculous. So regulations around that affect my work. Pretty clearly our business is heavily influenced by a lot of - we happen to have a lot of government support programs, like we have travel grants, R&D projects, we get a lot of support from the government on various staff training initiatives and stuff. So things around supporting the growth of the industry, that is helpful and I do like that and that is something that's cool. We're very thankful for that. There's all of the standard like you've got to make sure that you're running a safe operation but you have to do that anyway. Making sure you're not discharging nasty things in the environment, you've got to do that anyway. I don't think there's regulations there, but I think you have to do those anyway. That's just life, right? You can't hurt people. So yeah, customs. I hate customs.

W: What are the main applications of your work?

B: We sell sensors for measuring human body motion, so you take our sensors, they're like rubber bands with Bluetooth, you put them on your body. When you move, the rubber band stretches, and we measure that and then we can tell how your body's moving. So animation, gaming, virtual reality, sports and fitness, healthcare, anything where a human body is moving, we can measure it.

W: That's cool. What is your current approach to stay relevant in this rapidly expanding field?

B: I think there's three things you have to look after. One is brand, one is customers, and one is technology, and you need all three and they feed each other in a virtuous cycle. So you have to have the best technology if you're going to play in a niche and if you don't you have to find a niche where you do. I think that's just the price to get into the game, right? From that, though, you can grow a really strong brand. So by having the best technology, you can grow a strong brand and get a reputation for actually having the best. From that, you'll get the best customers and make the most money that you then re-feed into your technology development to have the best technology and you just iterate as fast as you can around those three things. Best technology gets you the best brand, gets you the best customers, allows you to develop technology the fastest.

W: How much money does your organization spend yearly on Research and Development?

B: It's tricky to answer because we do a lot of customer driven R&D. So it's difficult, if you're talking about R&D that is not paid for directly by a customer (...) engineering, right, then it's probably 5% maybe. Then we probably spend 10% on IP, and we probably spend another 10% on sort of customer driven R&D, something like that. We're a tech startup, so we have quite a large R&D and IP budget. So maybe all up 25, I kind of - I don't have a concrete answer for you, but 25% would be a mixture of IP (which I consider part of R&D), self-funded R&D, and then customer driven R&D at the moment. And that's a moving target, but that's probably a reasonable guess.

W: And how much money does your organization spend yearly on microfabrication in particular?

B: Well, according to your definition of microfabrication, which is feature size of less than 100 microns, and so if we're assuming that the material parts of what we're doing are that, I'd say about half of our R&D budget goes into that. Sort of 10 to 15%, but that's based on kind of loosely linking my sensor technology to microfabrication. I wouldn't - it's not like MEMS.

W: How many people does your organization have on staff?

B: 18 staff. Including various students and directors, about 25.

W: And how many people does your organization have on staff for microfabrication?

B: Again, with our loose definition, three maybe. Three or four.

W: Is your company looking to hire more staff?

B: It's very much kind of like a staircase, so we hire based on the work that we think we'll get in the next few months. Then we try to get that work, show that we can actually deliver and support the level of people that we've got, accumulate a bit of fat, and then we then hire again for what we think will come. So I'm constantly playing this game of getting the right number of people, because if you've got too many, it's too expensive and you're out of business, but if you don't have enough then you can't deliver on what you sell and you go out of business. So it's tricky, but right today? No. But I hired someone a month ago, so it just changes.

W: How do international trends shape the future of New Zealand microfabrication?

B: I think the trends - and Internet of Things, Cloud, big data, all these big buzz words...wearables, disappearables is what we're talking about now - I think all of them create great niche opportunities for smart technology companies. So I think that life looks pretty rosy from my point of view. I think the issue is New Zealand has to stop selling cows. Too many cows, it's ridiculous. And their environmental impact is insane, right?

W: What factors make it difficult to compete in a global market?

B: For anyone? Or for New Zealand microfab or for -

W: For New Zealand.

B: So yeah, distance is tricky. It just means you've got to travel a lot. It hasn't held us back, but you do have to travel a lot given the face time. What other factors...well I mean, competition can come from anywhere but opportunity can come from anywhere. That's kind of - it's like a double-edged sword, right? That's globalization, it's the fast and the dead. So you've got to move quick, you've got to be agile, you've got to be nimble and yeah, you could sell to anyone, anywhere but so can anyone else. So it's just all about speed. I don't know. I don't think New Zealand's any special or has any particular advantage or disadvantage really when it comes to globalization. Anyone can create a website, anyone can start selling product, anyone can buy some 3D printers and make something. And so the main thing is making sure that we actually do that.

W: So we just have a few more questions and then we'll be all finished. Do you have any additional comments that you'd like to make?

B: No.

W: Do you know of any other companies or research groups in New Zealand that have interest in microfabrication?

B: Well you're talking to Rakon? You've got to talk to Rakon, right?

W: We're in the process, yes.

B: Yeah, good. Talk to Rakon. You talked to the Photon Factory...are you talking to academics as well?

W: Yes….

B: You've talked to the Photon Factory?

W: Also in the process.

B: You've talked to the, what's it called? The nanofab facility down in Victoria. There's one down there.

W: Yeah, we've talked to a couple professors and a couple of grad students.

B: Yeah, talk to them. Yeah, I don't know many.

W: That's fine, thank you. Would you like to remain anonymous?

B: No, I think there's enough information in there that anyone could guess who I was anyway so there's no point.

Interviewee: Brendan O’Connell

Interviewer: Digital

Organization: Tru-Test Ltd.

Location: Digital

Date and Time: 20/1/2016 16:24:57

Question: What is your name?

Brendan: Brendan O'Connell

Q: What is the name of your organization?

B: Tru-Test Ltd.

Q: Would you like to remain anonymous?

B:

Q: Which part of the microfabrication industry are you personally involved in?

B: Research

Q: What part of the microfabrication industry is your organization involved in?

B: Manufacturing

Q: What is your job title?

B: Head of Business Development

Q: What is your job description?

B: I'm responsible for strategic, technical and market analysis of major new business opportunities, in alignment with the corporate strategy.

Q: What does the word microfabrication mean to you?

B: Manufacture of micro structures

Q: How does microfabrication play a role in your organization?

B: research interests in micro fluidic applications in sensor design for the agricultural sector

Q: How has miniaturization changed technology in New Zealand?

B: not sure

Q: What do you imagine microfabrication in New Zealand to be like in 5-10 years?

B: not sure - hopefully some possibilities for novel applications

Q: How do you see ongoing miniaturization affecting the future in 5-10 years?

B: inevitable improvements in technologies across many sectors

New sensors

Wearable technologies

Q: How do you think miniaturized technology impacts society in New Zealand?

B: opportunity in both applications and capability development

Q: What are the strengths of the microfabrication industry in New Zealand?

B: not sure

Q: What are the weaknesses of the microfabrication industry in New Zealand?

B: not sure

Q: How do you feel about collaboration with other organizations?

B: Important capability - we're small and niche, so need to collaborate to find scale

Q: What do you know about industry clusters and how do you see a cluster operating?

B: Have seen good examples in security space of companies with adjacent needs (but not fully overlapping) working well together

Q: How aware are you of the microfabrication facilities in New Zealand?

B: not very

Q: How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication field? Why or why not?

B: Yes willing, want to explore the role we can play as 'non-micro' electronics manufacturer

Q: Are there any environmental concerns with microfabrication and if so, what are they and how are they dealt with?

B: not sure, probably not more than other processes

Q: What types of government regulations affect your work?

B:

Q: What is your current approach to stay relevant in this rapidly expanding field?

B: Working with research partnerships on applications micro-fabricated components

Q: Is your organization looking to hire more staff?

B: yes, but not in this area currently

Q: What factors make it difficult to compete in a global market?

B: understanding of local market and customers

Q: What are the main and potential applications of your work?

B: with respect to microfabricated components - lab on a chip type applications in livestock systems

Q: How much money does your organization spend yearly on Research and Development?

B: NZD5m+

Q: How much money does your organization spend yearly on microfabrication in particular?

B: none

Q: How many people does your organization have on staff?

B: 550

Q: How many people does your organization have on staff for microfabrication in particular?

B: 0

Q: Do you know of other companies or research groups in New Zealand that have interest in microfabrication? Who can we contact and what are your connections with these people?

B:

Interviewee: Bryon Wright

Interviewer: Digital

Organization: University of Auckland

Location: Digital

Date and Time: 26/1/2016 13:23:10

Question: What is your name?

Bryon: Bryon Wright

Q: What is the name of your organization?

B: University of Auckland

and

Manufacturing Systems Limited

Q: Would you like to remain anonymous?

B: No

Q: Which part of the microfabrication industry are you personally involved in?

B: Research

Q: What part of the microfabrication industry is your organization involved in?

B: Student/Education

Q: What is your job title?

B: Senior Research Scientist

Note that the university is primarily involved with research and education, the company (MSL) is involved with research and development and manufacturing.

Q: What is your job description?

B: For the Uni:

To support the Auckland Microfab as a multi-user, academic and industry-facing facility, and to generate research outcomes for the MSI/MBIE Laser Microfabrication and Micromachining grant.

For MSL: will not be given

Q: What does the word microfabrication mean to you?

B: Microfabrication (MF) is a set of processes for making small, useful things.

Q: How does microfabrication play a role in your organization?

B: For the Uni: MFis being used to further research into biological, medical, and scientific applications. It has also enabled new enquiry into commercial uses related to microfluidics.

For MSL: enabling technology for new commercial applications

Q: How has miniaturization changed technology in New Zealand?

B: Aside from a few examples, it hasn't as yet.

Q: What do you imagine microfabrication in New Zealand to be like in 5-10 years?

B: I imagine there will be slow improvement to the MF research infrastructure, largely driven by Unis and large scale research institutes. This will have produced a few established, early-stage companies that rely on MF for their core technology.

Q: How do you see ongoing miniaturization affecting the future in 5-10 years?

B: Growth of the sector, one hopes.

Q: How do you think miniaturized technology impacts society in New Zealand?

B: NZs will benefit both from improved technological or medical outcomes and from the commercial growth enabled by MF.

Q: What are the strengths of the microfabrication industry in New Zealand?

B: Without strong infrastructure provided by government or established MF industries (e.g. semiconductor) NZ has had to focus on using existing resources for both commercial and scientific outcomes. This is a highly efficient approach and suited to the funding opportunities for a growing technology in a small country.

Q: What are the weaknesses of the microfabrication industry in New Zealand?

B: Lack of a trained workforce. Cost-recovery accountancy in research settings driving the focus away from innovation.

Q: How do you feel about collaboration with other organizations?

B: Essential for extending NZ's capabilities (e.g. via the ANFF)

Q: What do you know about industry clusters and how do you see a cluster operating?

B: Not much. Shared infrastructure? Bring like-minded people together in one place to get a critical mass effect?

Q: How aware are you of the microfabrication facilities in New Zealand?

B: Very. I co-founded the Auckland Microfab and have close ties with other institutions and companies with MF-related work.

Q: How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication field? Why or why not?

B: Open to the idea.

Q: Are there any environmental concerns with microfabrication and if so, what are they and how are they dealt with?

B:

Q: What types of government regulations affect your work?

B:

Q: What is your current approach to stay relevant in this rapidly expanding field?

B: Travel to conferences, keep current in literature.

Q: Is your organization looking to hire more staff?

B: As funding allows, it is certainly desired.

Q: What factors make it difficult to compete in a global market?

B: Lack of networking opportunities with both suppliers, researchers, and other MF-based startups.

Q: What are the main and potential applications of your work?

B: Medical microfluidics, diagnostics

Q: Do you have any additional comments?

B:

Q: Do you know of other companies or research groups in New Zealand that have interest in microfabrication? Who can we contact and what are your connections with these people?

B: Try Stretchsense

Interviewee: Cather Simpson

Interviewer: Rachel Ooyama-Searls

Organization: Photon Factory

Location: Auckland

Date and Time: 26/1/2016 14:00:00

Rachel: For our records, could you please state your name?

Cather: Cather Simpson.

R: And can you state the name of your organization?

C: The University of Auckland. And I run a lab called the Photon Factory.

R: Would you like to remain anonymous?

C: No, that's fine. You can use my name.

R: Which part of the microfabrication industry are you personally involved in: supplier, manufacturer, researcher, or student?

C: Researcher and manufacturer

R: Which part of the microfabrication industry is your organization involved with? Again, the same four options.

C: We do a bit of - when you say manufacturer, we don't manufacture micromachining equipment. We manufacture things with micromachining. So we actually do product development and all of that sort of stuff as well as doing research.

R: And what is your job title?

C: I'm an Associate Professor of Chemistry and Physics and Director of the Photon Factory.

R: In your own words, can you give us your job description?

C: So I run a large multi-user laser facility, state of the art in microfabrication as well as in spectroscopy and device development. We do everything from really fundamental science, looking at how molecules decide what they're going to do when they absorb light, to what I call targeted research which is where we're looking at solving longer term challenges for industry in the micromachining space. Most of our funding is in that space. And then the third type of research we do is very applied, so we have one spinoff company now and we're about to incorporate the second next week, all of which use micromachining like microfabrication as a tool.

R: What does the word microfabrication mean to you?

C: Manufacturing things very small.

R: How does microfabrication play a role in your organization?

C: In the university as a whole, or in the Photon Factory?

R: In the Photon Factory.

C: Then the Photon Factory, it's one of our central Research and Development (R&D) thrusts. So we publish papers in that space, we use it as a research tool, we use it as a production tool, and it underpins a lot of what we do in other areas as well We also collaborate with people all around New Zealand.

R: In your opinion, how has miniaturization changed technology in New Zealand?

C: So there are a few instances that I know of personally where miniaturization has led to new products being rolled out, it's led to improved capabilities. When I'm talking about those, I'm talking specifically about the types of things that we've had come out of our lab. And that's in the last, well, since 2010 which is when we opened. Miniaturization has been going on a lot longer than that, though. And so we have major industries like Rakon that makes GPS chips. So as their chips get smaller and smaller, and I have an sample upstairs in my office of chips that are this big to chips that are this big, really, really tiny, you can put more on and all of that sort of stuff. I'm not sure it's done anything for New Zealand different from what it's done everywhere else in the world.

R: What do you imagine microfabrication in New Zealand to be like in 5-10 years?

C: I think in New Zealand it will be much more widely accepted. New Zealand tends to be a bit conservative and the industry as a whole, as the manufacturing sector, doesn't look outside New Zealand enough in my view yet. But I think they're doing that now and I think there are certain areas in New Zealand, certain types of manufacturing industry, that are really embracing micromachining and microfabrication and I think that will continue to improve. I think it will continue to grow, probably accelerate.

R: How do you see ongoing miniaturization affecting the future in the next 5-10 years, if at all?

C: That's a really good question. I'm not sure that in many of the applications that we look at here ourselves - so we tend to use microfabrication to solve problems in other areas. So for example, microfluidics for the dairy industry or for diagnosis. The advantages in going smaller than say 10 microns or 100 microns for channel size, that's not going to do anything in those types of applications. Where miniaturization is going to help in those areas is in things like surface patterning and being able to more precisely and accurately and cleanly manufacture features, and in being able to put more things on a chip, and incorporate things like photonics with your microfluidics and so on. I think there are some places where going smaller and smaller will improve things. For example, many of the tests that people do for veterinary medicine or agricultural types of diagnostics and monitoring are still done in buckets or in petri dishes and things. And I think being able to move those into a micro kind of scale will definitely help water quality, all those sorts of things that New Zealand, as an agricultural, primary industries, and 100% pure green kind of brand, needs to be thinking about. I don't think we're going to lead the world in, for example, making the smallest features on a chip although we do have people who are doing quite high quality research in that, you know like the 22 micron and smaller stuff.

R: How do you think miniaturized technology impacts society in New Zealand?

C: In a lot of different ways. Of course everybody has cell phones, right? So, in the same way it impacts society everywhere I would say. I don't think there's anything special about New Zealand.

R: What do you consider the strengths of the microfabrication industry in New Zealand to be?

C: I don't think we have a very strong microfabrication industry yet, certainly not on a global scale. We do have a couple of companies: Rakon, injection molding type companies that are moving in the microscale, certainly at the state of the art. But I would say on the whole, we don't have a strong microfabrication industry. It's still growing. And so it's an exciting time, actually.

R: And what would you say the weaknesses are of the microfabrication industry in New Zealand right now?

C: The hardest thing about New Zealand in general, and especially for high tech things like microfab, is that we're far away and we're small. So a lot of the cutting edge microfabrication stuff is quite expensive and we simply can't afford to have a lot of it, if we have it at all. And so I think we end up doing what in New Zealand is called the Number 8 bailing wire approach, which you may have heard of. New Zealanders in general are very, very good at doing excellent things with not necessarily the best resources. So I think the advances that we're going to make in microfabrication are going to be some in development, but a lot in clever development. And rather than, say, always trying to get smaller and smaller and smaller, New Zealand is more likely to make a contribution in the form of applying microfabrication in different directions or in, say, smart materials. So we'll have clever ideas and use those to improve our manufacturing and the capability of our products, but we're not Silicon Valley or anything like that. Do you know what I mean? We're just not big enough. We don't have the infrastructure and the scale, and in a country with four and a half million people, we have to do quite a lot of everything, right? And we're out in the middle of the ocean, so it's quite different. It's really fascinating being here from the United States.

R: How do you feel about collaboration with other organizations?

C: Oh, we do it all the time. We work with Callaghan, for example. Oh absolutely, we're part of two of the large Physical Science Centres of Research Excellence, both the MacDiarmid Institute for Advanced Materials and Nanotechnology and the Dodd-Walls Centre for Photonic and Quantum Technologies. So I'm actually on the executive board of that one. And that's how we leverage those types of collaborative relationships, to do more with less.

R: What do you know about industry clusters and how do you see a cluster operating?

C: So the clusters I'm most familiar with are in Australia, although I know of some in the US. But the microfabrication nodes in Australia, or the fabrication nodes in Australia, are really I think a good model. And we've actually explored in the past the idea of making the University of Auckland's microfab one of the Australian nodes, sort of as a partner and talked about that kind of method at the dean level and just above. I think it would add a lot. The limitations I talked about before about New Zealand being very small, meaning that our microfabrication abilities are quite limited, we're very, very good in laser microfabrication. We're sort of right at the cutting edge of using ultra-short pulses to do microfabrication in new ways that can do things that standard microfab can't. But at the same time, there's a whole host of resources and ways to process materials and microfabricate things that we simply can't do because we can't do it all. So it would be great if we could become an associated node of a larger network.

R: How aware are you of the microfabrication facilities in New Zealand?

C: There's one at Callaghan and they do photolithography and things like that. There's a group down in Otago that's doing eBeam type work. They also have some work at Canterbury University, and then there's us.

R: How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication field here in New Zealand?

C: Absolutely, 100%.

R: Why?

C: Because I think it's the only way for us to be able to leverage what New Zealand can't do and do more, and do better. I think we need one. And I've been arguing for one, in fact a colleague and I here, the two of us essentially are the microfabrication people here on campus mostly, we've been talking about how to set something up like that that links in - you have to link in industry, government, and academics especially in New Zealand, in ways that you don't necessarily in the states.

R: Sort of changing gears here...are there any environmental concerns with microfabrication that you do? And if so, what are they and how are they dealt with?

C: Environmental concerns in what way?

R: Pollution -

C: Are you asking, do we pollute? Right, so the types of microfabrication that we're doing mostly, we don't have major concerns with things like arsenic in the water or any of that sort of stuff. And that's because we're not doing a lot of that type of microfab. We're mostly doing laser micromachining and soft photolithography and things like that. That's not to say it's not highly risky and we do quite a lot with safety. Most of our concerns in that space actually are in our deployment, so we make devices that look at waterways. Do you know what I'm saying? So it's not really - it's not us.

R: What types of government regulations affect your work?

C: Very few. We're mostly doing R&D.

R: What are the main applications of your work?

C: Oh, that's a good question. Let's see, we do everything from enable sensor companies to have better products and better bottom line to looking at how to implement micromachining in a surgical platform to - our spin off companies are sorting sperm by sex for the dairy industry and measuring important variables in milk on farm, point of cow diagnosis we call it. Yeah, it's wide-ranging. I think of us as an enabling lab. So we're just actually starting a new initiative where we're looking at doing diagnosis of cancer using a handheld spectroscopic device.

R: What's your current approach to stay relevant in the rapidly expanding field of microfabrication?

C: It's really challenging to stay not just relevant, but up to date. I read journals, not just the academic journals, but I also get the industry micromachining type magazines or journals or whatever they're called and try to stay up with that kind of literature. Actually talking to, in our area where we're looking mostly at laser microfabrication, talking to laser manufacturers, because they have to keep abreast of what's going on in order to make their products relevant. And so they always have their finger on what's happening. So I try to maintain a good relationship with those guys.

R: How much money does your organization spend yearly on Research and Development?

C: My lab?

R: Yes.

C: That's a difficult one. My annual budget, labs don't really run in the same way as like a company, but if you looked at how much funding I have to bring in to support the research that goes on, it's about a half million dollars a year. And we have somewhere upwards of, I think at the moment, about 15 million dollars in external funding. So that's a total amount of external funding that supports things, it also pays people and like I said, it doesn't really work the same way in industry.

R: How much money would you say your lab spends yearly on microfabrication in particular?

C: Are you asking me how much we spend outsourcing it? Like if we have a mask made somewhere at a place that's got better capabilities, or are you asking how much we spend internally?

John: What percentage of your Research and Development budget goes toward microfabrication?

C: So the bulk of our Research and Development money goes towards improving microfabrication. So our major grants are in that space, so I would say in terms of funding money, 75%.

R: This might not apply, but how many people does your lab have on staff?

C: We have about 30 people. About half are engineers; the other half are chemistry and physics people. Of that, I'd say it varies a little bit. You're right, it doesn't apply completely. I think we have five full-time members of staff, nine PhD students. Of the rest of those, we hire students like you guys. We pay you 20, 25 bucks an hour depending on where you are in your studies to come work on projects with us as well. And so right now we have ten of those because it's summer time here so they're on summer scholarships. And so they come in and do research. They get to meet companies and they get trained and then hopefully they go out and they find jobs and they start new companies of their own and the whole microfabrication/manufacturing industry in New Zealand goes *positive hand motion*. I have goosebumps.

R: Again, this doesn't completely apply, but is your lab looking to hire more?

C: Always.

R: In your opinion, how do international trends shape the future of New Zealand microfabrication?

C: I think international trends for us are aspirational. We certainly pay attention to them and we monitor what's going on and we publish in top journals around the world. But as I said before, we can't do everything, so we can't lead everywhere. So we have to be very selective about the types of things that we really focus on. And that often comes down to individual - in the university sector it comes down to individual interests. So we have some people in engineering, for example, who are really, really good at modeling on the microscale. And we have people like us who are really, really good at using lasers to make things on the microscale and that sort of thing. Again, the guys down in Canterbury and the guys down in Otago, and the companies then end up specializing when it's driven by what they need for a particular product. So I think we pay attention and, like I said, we monitor, but we're not trying to match those trends and everything.

R: What factors make it difficult to compete in a global market?

C: The size of the country and also the amount of research that companies do. They're very low here, so they put very little money into R&D, companies, and they often come with what they think are answers to the questions they have. So one of the biggest differences that we see between working here versus say in the United States, is a company will come to me and say, "you know, we're having trouble with this thing right here. Do you think you can use your laser to drill holes here, here, here, and here?" And we say, "Look, you should've stopped with 'we're having trouble.'" Because we're actually the ones keeping up with what's going on internationally. Because this is a plastic component in a lawnmower or something, you know what I mean? They're not paying attention to manufacturing and how to do things clever and fast and efficient. But they're so risk-averse and there's a funny - the community as a whole thinks of university researchers as, do you guys know the word (...)? So that's a New Zealand/UK word...fuzzy-headed, we sit in our offices and think up really crazy ideas that don't really have any relevance. So there's a lack of trust and there's a lack of confidence that we would be able to contribute anything other than a tool to drill holes that they want drilled. So I think that slows everything down, so in terms of per-GDP, if you look at the amount of R&D funding that the private sector, the industry sector puts into R&D, we're down almost at the bottom, down near the bottom of the (...) countries that are like us, including places like the US. I think the US companies might put in two or three times as much as we do. So they need to put more money in. They need to invite more of us onto their boards. And they need to just realize that you need to ask more people questions and listen to the answers because otherwise you're always going to be looking for nails to hit with a hammer that you happen to be good at, do you know what I'm saying? I think it's changing for the better.

R: So we're kind of at the end of our interview here. Do you have any additional comments you'd like to add?

C: No, except that I hope that this is not just an educational exercise and that actually somebody's thinking about putting a microfabrication node somewhere here in New Zealand because that would be really fantastic. We would love to host it here. That's a thing that we were kind of hoping for is we could maybe work with Callaghan to have a kind of satellite Callaghan here on site somewhere and build synergy that way. And that would be great because we've got the best lab down in the basement I think.

Interviewee: David Grant

Interviewer: Rachel Ooyama-Searls

Organization: Rakon Ltd.

Location: Auckland

Date and Time: 27/1/2016 11:00:00

Rachel: For our records can you please state your name?

David: I'm David Grant.

R: And can you state your company?

D: And the company is Rakon Ltd and my role is manufacturing engineering manager.

R: What part of the microfabrication industry is your organization involved in?

D: I guess first that depends on your definition of microelectronics. In your definition it was under millimeter sized products, I think was the definition. Traditionally, for me it probably means more to do with not necessarily the product being that small, but features within the product are that small, so micrometer type dimensions and so that typically would bring into mind, for me, asic devices or semiconductor devices, and probably if you'd asked me 20 years ago, before I came and joined Rakon, I probably wouldn't have thought much other than that, but these days Rakon certainly makes products with lots of features in them which are micron type scale.

R: Would you say that Rakon is a supplier, manufacturer, or research...

D: Definitely, well, primarily I guess a manufacturer, but with research capabilities.

R: And can you state your job title?

D: I gave you that already, but manufacturing engineering manager.

R: And can you give us a job description in your own words?

D: So there's a group, and your colleagues are interviewing Mike MacIllroy, he looks after the product design, which is the initial product design, I've got several teams, one of which does the parallel process design, so the manufacturing process design to make those products and then our product is one where you make a generic design, a family sort of design, and then as each customer comes in, they basically require some level of customization. So I have a product design team as well, who customize the designs for what we're doing, so this card sort of highlights some of the products that we make and so you can see some of these products are pretty small and then there's componentry inside these, so we customize those things, so the primary product that we make is to do with frequency control and so customers want different frequencies over different temperature ranges and all that sort of thing, so we customize a design for each one of those. So those are the two main teams. There's another group who do all the maintenance of the manufacturing equipment and facilities and the day to day frontline maintenance of the test equipment that we've got and each of those teams is about 15 or 16 people, so that's about 45 - 50 people involved in the manufacturing engineering team. So, in very broad terms, that's what I look after.

R: And how would you say microfabrication plays a role in your organization?

D: As I described before

R: Is it basically all you do?

D: Yeah, well, you can see some of our products get up to larger products but within those, there are semiconductors, asics and Rakon is a global organization but we have an operation in Harlow in the UK which is a design center for asics, so we actually design our own asics, so that's microfabrication design, design of componentry that products made by suppliers, for us, and so, but we have to understand what's in those products, so it's microfabrication involved in those products, and then those die chips, those semiconductor dies, we wire bond, we flip-chip mount into ceramic bases, so all of these things you can see are in ceramic bases, so, we have to understand those manufacturing processes, because they're just a service they provide just like contract manufacturers, who can simply do the wire bonding or whatever. So we actually have to understand all of the manufacturing processes we often have stuff done in Thailand for us, so we often send people up to Thailand to help them make sure the process is under control and so on. And design for reliability of those processes, understanding the issues you get with multiple metals and bonds and all those sorts of things. So we're deeply involved in that sort of stuff, and then there's the crystal itself, so the crystal determines the frequency, these components here are crystals. Again, there's a ceramic base, inside the ceramic base, there's a piece of quartz and then there's a lid put on. Now that makes it sound very simple, essentially but, it's a process of machining that quartz to size, which we used to do here in New Zealand, but now we subcontract to a joint venture that we've got in China. So that's a mechanical process to machine those pieces of quartz to size, but what we've implemented here, in our facility, and this is probably the bit that we don't want bandied around in the press too much, is to do with photolithographic processes for basically chemically etching those pieces of quartz to the very precise sort of dimensions that we require. So, yeah, those really are the areas in which we're involved in microelectronics. There's a bundle of processes in the assembly of this, & you've got to put a couple of blue dots on and you've got to make sure that it's not stressed because all of those things affect the frequency fairly dramatically, so yep, that's what we do.

R: So we're shifting gears here. How has miniaturization in your opinion, changed technology in New Zealand?

D: I guess in that context, New Zealand is a follower of the rest of the world, so it's probably no different than anywhere else, it's allowed us to have phones the same as you've got and all the rest of it, lots of apple products and nowadays Samsung products and a few others besides. Accessibility to information and so on I think has been facilitated by microelectronics in a very broad and general sense. A lot of where we sell this stuff into these days is into facilitating the internet and being able to provide the bandwidths that are necessary to get the huge amounts of data that we're all consuming now across the given number of pieces of wire, or fibre.

R: How do you imagine microfabrication in New Zealand to be like in 5-10 years?

D: That's a difficult question, I'm going to retire in a year, so I won't be around in the electronics industry to actually see that I guess, but I have had 40 something years in the industry, both in New Zealand and overseas. So what's it going to look like, I guess the changes in the last several years in New Zealand are that the number of people that are making strictly electronic products is very low. There's not many, for example, people making a component that's then sold to other electronics people, so some of the bigger companies are people like Fisher & Paykel and, I don't know whether you are talking with anyone there or not, but they're probably the biggest company in New Zealand, as far as having electronics in their products, but their business is healthcare business and I don't, it's about medical devices, and electronics is just a component of it, and that's how I've always seen the electronics industry in NZ, there's not many people who are as recognized name as an electronics supplier. They are people who make medical devices as in that part of Fisher & Paykel or the other half of what was Fisher & Paykel makes domestic appliances, washing machines and so on, and that also had electronics in it, so that's really what the New Zealand electronics industry is, there isn't much of what I would call microelectronics, per se, Rakon is probably the closest to it.

R: So how do you see ongoing miniaturization affecting the future in 5-10 years?

D: How big are your fingers? Yeah, how small can things get? And you've actually seen it in things like the phones you know, you went back five years age, the push was to just make them smaller & smaller & smaller until you could buy a mobile phone that was only a couple of inches square, pretty much, but then as that's converged with computers and tablets and so on, the size of the phone is now something that I wouldn't have dreamt of putting in my pocket a few years ago, it's too big, and so I guess there's limits in terms of the products, as to how small you can actually go. I guess it's more about packing more functionality and more capability into products, and I guess everybody's trying to do that all of the time, so I think it's not so much about the drive to miniaturize it for the sake of making something smaller, it's more to do with making it fit more, electronic functionality, software functionality into a piece of equipment

R: That makes sense, how do you think miniaturized technology impacts society in New Zealand? If at all?

D: I'm not someone who studies society in that way too much, but I don't think it's much different. Again, we can buy the same things that you can buy in the US or the UK, or Europe, or anywhere, and people do. The prices are probably a bit more expensive than they are in other places because we're a long way away from anywhere. Bit of its impact on society is that people have adapted, we don't talk to one another as much as we do, in the we send messages and all that sort of stuff and I think that's really where the technologies headed. Is it going to be a good thing? Not necessarily, I tell my guys make a phone call instead of sending an email and you can get a lot more done in a 1 minute phone discussion than it takes for you to type out something and think it out, send it off and wait a day for a response and you can get the whole thing resolved in a minute on a phone call and it all faced and going to see somebody. Sending an email across the room type things, that really annoys me.

R: So what do you consider are the strengths of the microfabrication industry here in New Zealand?

D: Strengths relative to anyone else, it's probably the whole attitude of kiwi society that can do, we can do things instead of finding ways why we can't do something. In fact, people often say the biggest challenge to a kiwi is to tell them they can't do something, so they'll set out and do it. That's quite a good attribute to have in people. As far as the engineers who come out of the New Zealand universities is concerned, I think the more generalist education that we at least used to get, I'm not sure that it's, I think it's maybe starting to get a bit more specialized, but I think the general degree sort of qualifies our engineers to go in & start doing just about anything, rather than specializing too much during the degree stage. So strengths, yeah, I think those things are part of the strengths.

R: Ok, & what would you say are some of the weaknesses of the microfabrication industry are here in New Zealand?

D: The same thing probably, as you try to do things you shouldn't. But I think probably the distance from other places and in terms of making things and shipping them, yeah, it's a long way to have to send a product. I think one of the questions later on is about how much do we supply, what other countries do we supply in New Zealand, well stuff all, most of our production disappears overseas, so it all has to be freighted. So geographic location is a significant factor against us. For somebody that's making something like a washing machine, I mentioned Fisher

& Paykel before, obviously that's quite a big impediment. For something that's small, it's not such a big deal, so for us, a reel of 10,000 of some of these components is fairly light, we can package it in a carton, and actually, we don't use normal shipment, we courier everything to our customers so we can get to a customer within a couple of days basically. So for microelectronics, if your whole product is truly small then it's not necessarily a big factor in geographic isolation.

R: How do you feel about collaboration with other organizations?

D: That's ok, I have in fact worked closely, I've worked in a few organizations in New Zealand, not many, literally a few, and throughout the career, we have collaborated with other-- This is all coming back to what I talked about with the electronics industry, we've collaborated with people who've used electronics in their product, but our products aren't competing, you know, I've talked about Fisher and Paykel healthcare, they're in the medical business, Tait electronics in the south island is in the mobile radio communications business. I've probably interviewed at different stages just about everybody in the electronics industry in New Zealand. You get to know people, and so you ring somebody up and say "hey look, we're thinking of buying an X-ray machine, I hear you guys have done that, do you mind us coming down and having a look", and all that sort of thing, so that sort of thing happens, and with the universities we have a pretty close relationship with Auckland and Canterbury Universities. So, yes, that's fine, I don't have a problem with collaboration, we do do some of that. Probably less organized these days, it is more up to individual relationships that you might have, rather than in the past there was an organization, the name of which has just deserted my mind, but anyway, it was like a meeting place, you know a networking group where people from the industry came together once a month, once every couple of months and talked about issues of common interest, like freighting, and tariffs on electronic components, or impact of tax rules on your ability to manage things and so on and people in R&D and all those sorts of things, and so you got to meet a few people through the industry and I certainly was very involved in that back in the days that that was an active organization, but the woman who was basically the driver behind it, I think retired and so it sort of faded out a little bit.

R: What do you know about industry clusters and how do you see a cluster operating?

D: What do I know about industry clusters? Well I don't know of any effective ones in New Zealand. In a cluster, I guess it's a grouping of geographically of organizations that have some elements of common technology. I keep coming back to this, is electronics a product? Or is electronics an enabling technology that enables people to design products whether it's cell phones, or washing machines, or whatever. For me, a cluster typically would be somewhere

where they have some common technology where they can support one another but it isn't in any way competing end product. For me, the difficulty with that in the New Zealand environment is given that we already have an informal arrangement that we can ring up anybody and say "look, can we come and have a look at x, y, z. Or do you have anyone with expertise in such and such an area" Does bringing people together like on a campus, which is sort of how I see it, I've sort of struggled to see a lot of additional benefit in that myself.

R: So how aware are you of the other microfabrication facilities here in New Zealand?

D: Again, what's your definition of microfabrication? I know that some of the universities are working on stuff that would be classed as microfabrication. Not too aware really of what other companies are doing. And if you said straight out can I name something that's microfabrication that somebody else is doing I think other than possibly some asic design work, and not even very much of that, I'm not too aware. People are using electronics quite extensively but would I classify much of that as microelectronics in terms of your definition of sub-millimeter product then my answer would probably be not much.

R: How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication field? And why or why not?

D: You started off with involved suppliers and one of the downsides of the cluster group that I've mentioned have been in existence before, networking sort of group, more than a cluster, anyway they're bringing together people to do stuff together was the involvement of suppliers. That was a pain in the a** because they were just there to sell stuff. So I have some reservations about suppliers being part of clusters. I guess I'd want to know what's the basis, the real common element that those clusters or companies might have that would actually give them a benefit of being part of that cluster. In the past if you look at it, it's a bit more large scale electronics but some of the sorts of the areas that people are interested in… The components would have been leaded components and so we started off with people hand assembling stuff when you go back to the beginning of my career but then not long into my career there were automated machines to put leaded components into circuit boards. And then there was the whole introduction of SMD componentry. So then the machinery changed for that and… So a lot of companies share information about the equipment, about the process settings, about the problems they were having and the industry didn't form a cluster but those that were doing that sort of stuff talked to each other and shared that sort of thing and then as that entity became a long standing process, a mature process, then that grouping or that need to talk together so often would have drifted apart. If I've got a problem with something on SMD or instead of using, hey let's take that a few years ago literally solder became flavor of the month instead of leaded solders and Rakon was probably one of the first to push into lead free soldering so then when other companies started, we had phone calls all the time "can we come have a talk with the advisor doing…" So those sort of relationships do exist. So do you need a more formal cluster or not? And I guess right now what is that common thing that would actually give them the benefit of being together either in their given locations or around the country but having a forum to come together on or even for putting them on a common site with some shared facilities. And I guess one of the reasons people do that clustering is more for startups that maybe don't have all of the human resources and material or sharing photocopies and that sort of thing. I mean, often a cluster is around those sort of startup situations. I'm not sure how many startups New Zealand's had in recent times and it's not so much orientated to electronics people. People in the technology arena are more often involved in software type things these days.

R: Are there any environmental concerns with microfabrication that you know of? And if so, how are they dealt with?

D: Well, I guess there's no more concerns than any process industry that uses Chemistries and so on. For sure we use a lot of chemicals in our manufacturing processes but so the issues there are really about managing the waste and meeting the legal requirements. It's just a fact of life. We don't want to s*** in our own nest if I can put it bluntly. As a company, we take a responsible approach to that. For example, all of the water that we use in our manufacturing process we have a wastewater treatment plant so we neutralize it completely before it's put down the waste sewer lines. There's the use of metals, cadmiums, and golds and all those sorts of things so our manufacturing process is one where if you put 100 products in at the beginning of a production process, you don't get 100 out the other end, you get a yield. There is waste, there are rejects, its part of the process. We're pushing the boundaries of what's capable with the technology and so some of those components we send off are waste management for recycling the precious metals and some of the other not so good for the environment metals, cadmium and so on.

R: What types of government regulations affect your work?

D: All of the laws of New Zealand. You're not allowed to kill somebody. There's obviously the environmental legislations, there's normal human resources type policies, minimum wages and all those sorts of things that come into play but just the normal laws really, there's nothing too draconian targeted at the electronics industry specifically. A lot of the pressure on us to, for example, I talked about being one of the first to move towards lead free, that wasn't pressure from New Zealand. New Zealand's not going to be the leader in the world about some of these environmental issues. In a legal sense, it's going to be more of a follower. Actually it was pressure from our customers that drove us towards those things rather than necessarily legal local law type issues.

R: What are the main applications of your work? I know you talked earlier about frequency stuff.

D: It's all about providing very precise frequency over significant ranges of temperature so these things, oscillations of quartz is mechanical or electromechanical material. In very broad terms, if you apply an electric field to it then it tries to sort of bend the quartz and then when you let it go, it swings back in the other direction and in the previous electric field and it does that at a very precise speed determined by the thickness. So typically we're talking about frequencies from 10 MHz to in standard crystals, up to 50 MHz but we're actually delivering products up into the Gigahertz range. The stability of a crystal on its own is plus or minus maybe 20 parts per million so 10 MHz is going to have a variation of plus or minus 200 Hz. That's the stability of the raw crystal. What we do is we put it into a product because the crystal can't work on its own, it needs an oscillator circuit to drive it and so we match the crystal with various oscillator circuits that you see in the various form factors here. In those, we essentially bug away that plus or minus 20 parts per million is across the temperature range from about -40 to +85 degrees operating range. So we do that then put it into these oscillators here when we then get plus or minus .1 part per million.

R: Are those degrees Celsius?

D: Yes. .1 parts per million stability. If we then build it into these types of products here, we actually get down to parts per billion of stability so we're talking about very precise frequency control. Rakon made its name originally in providing those for the GPS industry. So at a certain point in time before phones started providing GPS functionality when you're talking about the personal navigation devices that people have in their cars, all those sorts of things. Rakon actually owned 65% of the world market share. Or better than 65% of the world market share. As it's gone into phones, we actually chased that market for a while but it sort of all came together with the building of a plant in China to service that industry but sort of global financial crisis and all that stuff happened and things changed and as a result of that, there was a significant impact on Rakon's financial results. We actually decided to get out of that market. So we decided to get out of the mobile phone part of it, we're still in the other part of the GPS market and that was to do with what we offered, what we were offering in the way of stability and performance was better than anybody else could do. And that probably still is in those products. While all of that was going on, we already started to get a lot more into the telecommunications industry. So with some of the more precision parts we're selling to Ciscos and the telecommunication infrastructure companies Erickson and (...) and some of those sorts of places. Samsung and Wai way in China and I guess that's where really now our core business is in providing frequency control for those guys. So what they need is, they have a link whether it's microwave or fiber or whatever and that's sending a little bit of your data down at this instant and then the next instant a little bit of your data and the next instant a little bit of mine for example. To make sure that your data and my data don't all get mixed up, they have to have guard bands in between. Now the more precise your frequency control is, the smaller you can make those guard bands and that's basically what the stuff enables. By having very precise frequency control across a wide temperature range, you can get lots more data into your system. So that's really what a lot of Rakon's products facilitate. And people use them in other things as well but fundamentally, that's really what you're talking and there's also some military and defense applications and you can see that on our website. As to some of those applications, we work with (...) in the US for years around some of that stuff. And that actually started with GPS type stuff as well. There's a branch of our business in France which is making stuff for the space industry. So you also find a number of Rakon's parts in the satellites orbiting globe for telecommunication satellites and yea, a little bit of everything really and I've forgotten exactly what the question was now but those are the products that we have and the main markets that we're targeting.

R: What's your current approach to stay relevant in this rapidly expanding field?

D: My job isn't to do with the product innovation directly so that's who your colleagues are talking with so he's probably talked to them a little bit about what he does. Rakon is quite a leader in many regards but there are some conferences and so on that we attend and I guess the key thing is our approach to the market is very close to the end customers who actually design the things and so we get early discussions going with them about what might their product need for the future. We also work very closely, because all of these things work in conjunction with chipsets that come from really only a handful of key telecommunications chipset manufacturers around the world. So we also work very closely with them so that our parts are specified as part of the referenced design that they put out that then all the other users of their chipsets use. And I will only guarantee that our chipset will work if you use a Rakon crystal, a Rakon oscillator. Staying close to customers is a pretty important part for us. In the manufacturing side, suppliers are often a really good source of information as to what trends are happening and what other people are doing. They're supposed to remain confidential as to what equipment they are supplying to other customers or other manufacturers around the country. That's why I don't really think that they should be a part of a cluster. They are pretty loose lipped bunch of people to be honest. Don't tell them that probably but. So there's actually reasonably easy to find out what's going on as far as manufacturing technology is concerned. As I've mentioned before, we keep in close touch with the local universities, engineering universities, here in New Zealand. And they've got links into other universities as well around the globe and actually one of the guys that's working on the photolithography process that I mentioned has spent quite a bit of time in the research lab in the University of Melbourne in Australia in recent times and is working closely with a group attached to Victoria University in Wellington. Through those sort of places, universities are always places that keep a finger on the pulse as to what's happening around the globe. Sometimes they want to try and get into the technology long before it's sufficiently mature for an industry to actually be using it. So we have to take some of that with a grain of salt but none the less it's a feed to keep you informed to what's going on. But the other thing is you can find just about anything on the internet these days if you're interested enough to find it.

R: How much money does your organization spend yearly on research and development?

D: Depends on your definition of R&D but the way that it's published and in our accounts it's about 6 million dollars.

R: How much of that money would you say is spent yearly on microfabrication in particular?

D: What do we class as microfabrication? I could say that that's a hundred percent. Some of it's on some of these bigger devices but inside those there's microfabrication as well so I'd say that's it, that's what our business is.

R: How many people does your organization have on staff?

D: In New Zealand? 350, it might be plus or minus 20 at the moment because we change a bit. It has at its peak been 540.

R: Do you know how many staff are here specifically to do microfabrication?

D: Well all of them are involved in making or designing these products. Some of them finance and accounting and stuff but excluding a few administrative roles, it's a fairly large engineering team, 80-odd engineering team and most of the rest would be involved in the manufacturing of those products. You might be able to take 50 out for HR, finance, and production planning and that sort of stuff.

R: And is your company, you think, looking to hire more staff?

D: In what time frame? If we talk about the future, probably not so immediate. Rakon in relation to this downsizing I talked about with the pulling out of the cell phone market. We've got up to making about 10 million products every month where as now, most of that 10 million which was going into cell phone business, into [redacted] various other products is mostly gone. So it's a much smaller staff and while we're building this up, we're all aware of people are worried about the world economy at the moment so is our business growing significantly as of today, probably not that much that we would be going out and recruiting. But in terms of the long term, Rakon will always have expectations of growth, most businesses do. So yes, I can imagine that in the future years there can be growth of staff members. Come back to the fact that we are a global company and where those staff might up being in New Zealand, or France, or UK, or maybe China.

R: How do you think international trends shape the future of New Zealand microfabrication?

D: As a country, we're not a major producer of components for microelectronics. So we tend to be a follower, we use technology that's pretty much come from elsewhere and we apply it into our own products, it may be in some innovative ways. But mostly, the technology actually comes from overseas. Now, there will always be somebody tinkering away in some research lab at some University or somewhere and they come up with something and decide to make a business from it. But that hasn't been a huge source of new economy for New Zealand, if I can put it that way. So I think the trends will really be determined by what's developed elsewhere and for us, the trends for the products that we produce will be dictated by the needs of those businesses, our customers, where the trends in their businesses head. If somebody gets to a point and says we found a way now that you don't need to transmit as much data around the globe and you don't need to expend the networks, I can't think of how'd they do that but if somebody did, then it would obviously impact what we were doing. But if they say, hey look we need a frequency control product that's at 5 GHz in order to time and synchronize all our data networks and so on, then Rakon would be developing product for that and that would be what dictate-- so for us, very applied is what I'm saying. What we do is applied to the needs of the markets that we are supplying into.

R: What factors do you think make it difficult to compete in a global market?

D: For New Zealand?

R: Yea. This might be difficult because you have an international company.

D: I guess one of the things is that, and it's part of the reason for some of our international business, is that there isn't much of a microfabrication activity in New Zealand, it's mostly applied in the electronics industries and the upside of that is if for example, you wanna design a semiconductor, an asic, or something for your product, there's not much in the way in terms of skillsets for doing that which is why we have a design center in the UK that does exactly that. Because there's quite an infrastructure in the UK that supplies that sort of industry both infrastructure out of the universities where people are taught the design skills you need for doing that sort of thing through to suppliers that supply the equipment for the design and support it. We can get the equipment but it's a bit of a long way to have to pay for a technician to come to New Zealand to service a piece of equipment that may not have local support. So I guess for me, that's the biggest obstacle for microelectronics in New Zealand, the training comes back to the generalist training I talked about earlier on for the engineers. It's not so specialized and to hey I learned how to design a cell within a semiconductor or a device.

R: We're coming to the end of our interview here, do you have any additional comments?

D: No.

Interviewee: Eva Weatherall

Interviewer: William Boyd

Organization: Victoria University of Wellington

Location: Gracefield

Date and Time: 21/1/2016 10:30:00

William: What is your name?

Eva: Eva Weatherall

W: And what is the name of your organization?

E: I'm a student studying through Victoria University of Wellington, I'm based here at Callaghan Innovation and we kind of work alongside Izon Science which is based in Christchurch but there is no official connection between us and them. I just used to work there and my project is based around their instruments.

W: Thank you. Would you like to remain anonymous?

E: No, that's fine.

W: Thank you. Which part of the microfabrication industry do you consider yourself to be a part of? Supplier, manufacturer, research, or student?

E: Student and research, I guess, but student.

W: What part of the microfabrication industry is your organization involved in? Same options. And you can pick the institution that you feel most affiliated with.

E: I might say what each one is involved with if that's helpful. Izon will do manufacturing and research and then Victoria is just research and I'm a student there.

W: Thank you. What is your job title?

E: PhD student.

W: What does the word microfabrication mean to you?

E: Making small stuff.

W: How does microfabrication play a role in your organization?

E: So I work with nanopores. Nano is a bit of an exaggeration, they aren't that small. And they are in a turnable membrane and so you can make them bigger or smaller by turning a handle and stretching them. And we use them to measure the size of nano and microparticles, size, concentration, and charge as they move-this is probably going to be too much of an answer to this question-but so the microfabrication part is probably making the tiny holes which I don't do but I do use them. And Izon makes the tiny holes.

W: How, in your opinion, has miniaturization changed technology in New Zealand? And this could be as broad as you want to make it. This could be consumer technology, it can be industry.

E: I don't really have a good answer.

W: What do you imagine microfabrication in New Zealand to be like in 5-10 years?

E: Better?

W: How do you see ongoing miniaturization affecting the future in 5-10 years?

E: I guess lab-on-a-chip style stuff and stuff like that coming into more general use.

W: Awesome. How do you think miniaturized technology impacts society in New Zealand? If at all.

E: I don't know.

W: What are some of the strengths of the microfabrication industry in New Zealand?

E: I don't know it very well. Pass

W: What are some of the weaknesses of the microfabrication industry in New Zealand?

E: I guess New Zealand is quite isolated and therefore has less resources and stuff but that's true of anything. Researching, yea.

W: How do you feel about collaboration with other organizations?

E: Good. We collaborate with Izon-ish. Not like any official capacity but we like to keep involved with them because we can help them a lot. Because we have time to research and they don't because they've got other stuff to do. So yea, I think it's important. We do do it and it's helpful for us and them.

W: What do you know about industry clusters?

E: Nothing.

W: Alright. How aware of you of the other microfabrication facilities in New Zealand?

E: I know they exist. There's a cleanroom here where they do stuff and there's one up VIC Natalie Plank's group has one and they do stuff so I guess if I needed microfab done, I know who to go to.

W: How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication field?

E: Don't think they'd want me to join. They'd probably be more interested in Izon as a company. And I don't know how they'd feel about that. As an individual or me and my supervisor we are always interested in collaborating and stuff so I guess interested ish.

W: Would you be interested in joining a company involved in a cluster initiative?

E: For sure.

W: Thank you. Are there any environmental concerns that you know of dealing with microfabrication?

E: No. But there probably are. They use some nasty chemicals sometimes. Andrea and them are always talking about HF and I know that's not nice stuff so there's probably some but not in what I do.

W: What types of government regulations affect your work? If at all.

E: Don't think any that I'm aware of.

W: That's fine. Now we're going to move on to questions specific for students.

E: Awesome, I'll do my best.

W: Are you doing any research in microfabrication?

E: Not fabrication per se but using a sort of microfluidic setup.

W: Do you mind going into more detail?

E: What I do? Yea. So I work with these nano and micropores which are in a turnable membrane and that sits on an instrument so you can make the pore bigger and smaller on the nanoscale by turning the handle on the nanoscale. It's in a fluid cell and you have electrodes and you put an electrolyte in there and you apply voltage and you get a current through the pore and then if you add a sample of particles that you're interested in to one of the fluid cells and they flow through the pore you get a pulse because they increase the resistance as they go through the pore. So you get a pulse and bits of that pulse tell you different things about the particle. So you can analyze your sample particle by particle by looking at these pulses. So we've done a lot of stuff on measuring particle charge. With the setup and also other interesting things that happen when you've got a nanopore.

W: Do you know of any applications of this research?

E: Yea, so all of what we does helps Izon as a company and also helps users of the instrument which is a really broad range of people who use it. A lot of people use it to look at exosomes, bacteria, viruses, so it's like your biological stuff and then just some… stuff as well, people want to know how big their drug delivery particles are, stuff like that. What charge they are, how they change in different conditions. People have been sticking aptamers, which are like bits of DNA or RNA that sense proteins, and they've been sticking those on a particle until you measure your particle with aptamers on it and then you add your protein and you can tell the difference so you can sense whether they're there or not. Stuff like that. So everything we do helps the people who use the instrument as well as Izon, the company, for just improving their technology.

W: Thank you. Are you looking to get a job in New Zealand? Or somewhere else?

E: New Zealand. Because my boyfriend lives here.

W: What degree or degrees are you pursuing?

E: A PhD in Chemistry?

W: Why are you looking to get a job in New Zealand?

E: It's a bit of a silly reason but my partner works for Met Service which is the weather forecasters in New Zealand and there's only one in Wellington. So that's for the moment, while he's working his way up, I'll be staying in Wellington regardless but maybe later in life I'd move overseas.

W: Just a few wrap-up questions and we'll be all done. Do you have any additional comments that you would like to make?

E: No. I can't think of anything

W: Do you know of any other companies, research groups, could be other students in New Zealand that might have interest in microfabrication?

E: Yea, you should talk to Izon. I can give you a contact person after this.

Interviewee: Frederick LeCarpentier

Interviewer: William Boyd

Organization: Spark Transducers

Location: Gracefield

Date and Time: 18/1/2016 14:30:00

William: Also, would you like to stay anonymous?

Frederick: It depends on the questions that you are going to ask. Because I am working for a private company.

W: Which part of the microfabrication industry are you personally involved in? This could be a supplier, manufacturer, research, or student.

F: Yes, more research.

W: Also, for our records, could you please provide your name and the name of your company?

F: My name is Frederick LeCarpentier and my company is Spark Transducers.

W: Thank you very much. What part of the microfabrication industry is your organization involved in? Again, this is supplier, manufacturing, research, or student.

F: Yea, research and government.

W: What is your job title?

F: I'm a Senior Research Engineer, I do product developments.

W: And in your own words, could you provide a job description?

F: Basically my company, we develop and manufacture transistors for New Zealand and overseas companies. Basically they come to us with specs and we design the fabrication process and send it to them. And part of the process is to use microfabrication facility.

W: What does the word microfabrication mean to you?

F: Mainly for what I'm doing, it means developing multi-layers of insulators, conductors, and putting things together to form a working device.

W: Thank you. How does microfabrication play a role in your organization?

F: Without it, I won't get any device out of it.

W: How has miniaturization changed technology in New Zealand?

F: Has it?

W: In your opinion.

F: New Zealand is a very small place and not many people use microfabrication. There is no industry. That's why most of our clients are from overseas. It's more research and development than universities.

W: What do you imagine in your opinion microfabrication to be like in 5-10 years?

F: Tough question. You have to keep up with all of the technology. I think you will have quite a bit invested in state of the art equipment.

W: In your opinion, how do you see ongoing miniaturization affecting the future of New Zealand in 5-10 years?

F: Yes, it's the way things are going. For what we are doing in my company that's definitely the way, the future that they want. Smaller, higher frequency devices and the only way to do it is through microfabrication so that is very important.

W: How do you think the microfabrication industry impacts society in New Zealand? And this includes attitude towards technology as well. How do you think miniaturized technology impacts the everyday New Zealander? Or does it impact them?

F: Well that's the question. I was going to say, does it really? As I said, most of the microfabrication we do is more research and development and I don't know if it has impacted New Zealand industry or New Zealand people much.

W: In your opinion, what are some of the strengths of the microfabrication industry in New Zealand?

F: Again, is there a microfabrication industry in New Zealand yet? Is my question. Is there?

W: I think by industry we mean more the microfabrication facilities of the companies here and New Zealand. What are the strengths of having your company in New Zealand versus other countries? Or what are its strengths in New Zealand? Or does it have any strengths?

F: I think what's good here and what we are good at is we do what they call the kiwi way. We always find a way around. We are very flexible and we can adapt to technology and find a way around it. We are used to not have the best state of the art equipment and we can build our own and processes and stuff.

W: Before you mentioned New Zealand is smaller on scale compared to other countries and the lack of facilities. Do you know any other weaknesses of the microfabrication industry? Or would you like to elaborate more?

F: Give me an example of some New Zealand company that uses microfabrication on a daily basis. I can think of a couple in Auckland. We do. This side of research and development or university. Size is very small. Market is very small.

W: Thank you. What do you know about industry clusters?

F: Not much.

W: Alright. How aware are you of the microfabrication facilities in New Zealand? This could be universities, labs…

F: I'm aware of all the places because microfabrication facilities. Over the years I've been in touch with people there and using some of their of their equipment or them using some of our equipment. Being in Auckland and Christchurch, Wellington, Victoria University.

W: How willing would you be to join a cluster initiative for microfabrication? And why or why not?

F: I guess I would. I guess it will have to be depend what I am doing. Strong increase of doing some commercial products so doing research, just research. We aren't really applied but it would have to make sense for what we are doing.

W: Are there any environmental concerns with microfabrication and if so what are they and how would you deal with them? Or how do you deal with them?

F: I can't really think of any concerns, no.

W: Alright. What types of government regulations affect your work?

F: None. We are quite free to do what we want. We work in a non-destructive testing industry. We don't do like medical stuff.

W: What is your current approach to stay relevant in this rapidly expanding field?

F: Always try to take up the best technology, the best process, stable process and you know? Always try to do better than competitors, I guess. And that's why some people have come to us. Some competitors, their products are not reliable but I've managed to work on reliable processes.

W: Thank you. Is your company looking to hire more staff?

F: Yes. But not necessary in the microfab area. Microfabrication is a part of what we do. It's not the main part.

W: How much do you spend R&D wise in your company? Or I guess, give a percentage on how much is for microfabrication.

F: R&D is probably 50% of what we do but microfabrication used to be a bit years ago but it's 20%, 10%, 10-20%.

W: What factors make it difficult to compete in a global market?

F: Size. Competing with sometimes big places. Hundreds of employees.

W: So back to the scale?

F: Exactly.

W: What are the main and potential applications of your work?

F: Application is in non-destructive industry testing in the industry. So we've got clans settle this mock companies overseas.

W: You said earlier that you have done a lot of business with other countries. Which country do you do the most business with?

F: At the moment, it is Canada. Mainly Canada.

W: Thank you. Just a few wrap up questions. Do you have any additional comments that you would like to share with us? It is alright to say no.

F: No. None at this stage.

W: Do you know of any other companies or research groups in New Zealand that have interest in Microfabrication and who can we contact and what are your connections with these people?

F: Rakon would be one that comes to mind. There is SGS group. Robbinson Institute.

W: Can we use your name in association with your company's name?

F: That is fine.

Interviewee: Gideon Gauss

Interviewer: Rachel Ooyama-Searls

Organization: Victoria University of Wellington

Location: Wellington

Date and Time: 20/1/2016 14:00:00

Rachel: For our record can you state your name

Gideon: Gideon Gauss

R: And can you say who your organization is?

G: Victoria University of wellington

R: Which part of the microfabrication industry are you personally involved in? Supplier, manufacturer, researcher, or student?

G: Pure research

R: Which part of the microfabrication industry is your organization in involved in? Again the same four options.

G: Research

R: What is your job title?

G: I'm an academic

R: In your own words can you describe your job description?

G: I guess like most academics somewhere between teaching, research and administration.

R: What does the word microfabrication mean to you?

G: Well I guess in the end devices that is probably not easy to make on a let's call it a normal tool scale and so yeah I would maybe stop at that. I guess there is a little bit of overlap with conventional workshop tools to a small extent but it's probably at the end where one workshops tools are getting too large to do the job and two where there is a certain potential for a certain amount of repetitive production that is facilitated by microfabrication.

R: How does microfabrication play a role in your organization?

G: I guess speaking for myself there's a limited of microfabrication in terms of thin form deposition, in terms of basic let's call it microfluidic type devices. Within the larger organization it's probably more extensive just in terms of device fabrication and so on but all very much at small one off research scale rather than anything else.

R: How has miniaturization changed technology in New Zealand in your opinion?

G: Interesting, I think compared to many other countries microfabrication is probably a very shall I say a very selective field in terms of there's very few real commercial industries as far as know there's a large quartz manufacturer in Auckland which I think is probably largely used let's call it borderline microfabrication techniques for a long time as far as I know they sort of moved towards what you probably see as real microfabrication over the last few years. So within New Zealand I guess there's its sort of difficult to know all the little niches but I'd say it's probably rather a collection of small efforts rather than a single large organization that's easy to point to.

R: What do you imagine microfabrication in New Zealand to be like in 5 to 10 years?

G: I would hope it's a growing area. I mean it's one of those areas that I guess when you need a facility it's often nice to know where it can be done and if it's local it's better. I guess there's a lot of work being outsourced internationally these days but it's even in today's world where the world is smaller it's still, I think there is a certain amount of comfort to have it done closer to home rather than overseas. So yeah I would really hope that the microfabrication facilities do grow and that they do complement each other. We've got a clean room facility for the last probably 4 or 5 years at the university which we didn't have before so that's an aspect of microfabrication locally that is grown for us. We're not trying to do everything because one we can't afford it and but yeah I think that sort of yeah to me it would be hopefully grow and hopefully that different people will be specialists in different areas and that these people can help each other along the way.

R: How do you see the ongoing miniaturization of technology affecting the future in the next 5 to 10 years or do you?

G: yes I probably do. I guess I don't see any of the let's call it microprocessor line that's on an intel factory floor as being relevant to anything in New Zealand simply because it's an order of magnitude or several orders of magnitude cost factored to many all of that but to some extent I guess there's whatever you're doing there's probably a drive for some sort of miniaturization whether that's sort of stepping down from a centimeter to a millimeter scale or from a millimeter to sort of the hundred micron scale. I think when we talk about miniaturization and microfabrication yes there's these different length scales that are sort of slightly different two different people in two different areas but I think there always will be a driver for that and probably with that is the cost issue and the simplification issues and so and so. I don't see it as being not relevant to New Zealand I see it as being relevant for different people in different ways

R: Do you think miniaturized technology impacts society in New Zealand and if so how?

G: Yes it does I mean I think we're all impacted by it. And whether it's our cell phones first shrinking and now seems to be getting bigger again or things like that so yeah it does. And you know you can probably take the same into agriculture if sensors can be made small and put in vineyards that's going to benefit agriculture it's going to benefit New Zealand. So yes I mean it is relevant to many areas that are sort of non-electronics related but it's probably finding those areas and other footing

R: In your opinion what are the strengths of the microfabrication industry in New Zealand?

G: Interesting I would probably say it is how to say there is a single strength. I think to my mind it's probably a little bit of a variety of people doing different things and they probably can benefit from a more concerted effort in one or two types of projects to bring things together if I can put it that way. I mean there's apart from the quartz manufacturer that I've mentioned I don't know that there is a huge commercial activity that's absolutely based on microfabrication. So yeah I'd sort of hesitate to say what is clearly a strength in the, because I don't think there's what I can identify as an absolute strength at the moment.

R: What do you feel the weaknesses of the microfabrication industry are in New Zealand?

G: I think a little bit more exposure to what different people does I think would be good. I do think we're a little bit, despite the fact that we're a small country I don't think there's enough exposure to different facilities' strengths and weaknesses and I think often we can do with knowing a little bit more what's going on in Auckland

R: So more communication between sectors facilities?

G: I think that I mean we probably still all the facilities we have together might well be the size of an average size university facility in the States you know so. I do think geographically because we are apart that we do need a bit to find out what other groups can do so that you know where a problem can be resolved

R: How do you feel about collaborations with other organizations?

G: I think its good I think its expensive facilities that in the end probably can only really run if you do work outside of your own organizations.

R: What do you know about industry clusters and how do you see a cluster operating?

G: I've got no real involvement with a cluster at the moment. I think it's probably one of those things that tend to struggle 4 times out of 5 and maybe in the fifth case is successful. I think it needs a wide variety of partners if I can put it that way so in other words it needs people who do commercial work right through to people who sort of are more in the research area of it. So yes I think it's a very nice concept but I think it's sometimes not that easy to make it work.

R: How aware are you of the microfabrication facilities in New Zealand?

G: Shall I say semi aware I mean I have been in Canterbury, I've been in obviously the Callahan facilities. I've got a fair idea of what going on there without being absolutely clued up on what they're doing in terms of the facilities and with the Auckland microfabrication facility if that's what they are called I haven't even been inside their facilities so I would say semi aware.

R: How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication field and why or why not?

G: Yeah I think it will be good. So I think we, the facilities are so expensive to run that yes you want to know where else than your own lab your problem can get solved or quite often with these things it's a specialized little job that needs to be done that somebody else can do better than you so yeah by all means

R: Then are there any environmental concerns with microfabrication that you know of and if so what are they and how are they dealt with?

G: I think any microfabrication facility has a whole lot of potential risk issues associated with mostly the chemicals that get used and the disposal of it and so on. You'd hope that any fabrication facilities have got a competent lab manager that does those sort of things in a responsible way. So yeah probably that's largely the issue, materials being used, chemicals being used, disposal of them if from an environmental point of view

R: Do you know any specific chemicals or specific disposal methods?

G: Over here things we've got a safety officer and safety procedures so chemicals there's certain rules for using certain chemicals. There's a few things where I guess we err of on the side of caution and we don't use in the clean room because I guess we feel we're not really setup to do it well. Things get disposed of in the prescribed manner of liquids and solids and so on so. Yeah I'm pretty happy with the way things get done here to some extent also I think it works through to general lab stuff because in many cases people who use the clean room slash microfabrication facility that we've got also use outside labs so you know some can be done outside of it and same thing goes for that yeah.

R: What types of government regulations affect your work if any?

G: Probably health and safety type regulations that I know there have been a few changes in the New Zealand environment in the last 6 months or so. Yeah I guess that's probably the one that comes to mind.

R: What is your current approach to stay relevant in the rapidly expanding field of microfabrication?

G: Probably first put it this way that I guess I'm sort of a little bit on the edge of microfabrication. I do many things outside of the clean room type area because it's not necessary both due to sort of sizes or the cleanliness issue or that type of things. So I don't necessarily try and stay absolutely relevant in microfabrication as a whole but rather in sort of my interest areas which not all of that is absolutely microfabrication. I try and attend a sort of international conference once every 2 years and do the normal type of academic reading that is required yeah.

R: Do you know if your organization is looking to hire more staff specifically for microfabrication?

G: I would sort of say pass on that one. I think the way that people often get or academics get appointed at universities is that you know you wouldn't specifically in most cases you would not necessarily go looking for somebody in microfabrication but you know you'd go looking for a good academic and if they're then in the microfabrication area it might be good but it's not to say you will be, which is not always the case but

R: perhaps the case right now?

G: perhaps the case right now. I guess with technical staff it's like different if you want to appoint a technician then you might want to look for somebody that's got specific relevant experience. I don't see you know any specific growth within our organization specifically on the microfabrication front at the moment.

R: What factors do you think make it difficult to compete in a global market as far as microfabrication goes? Or even just technology, high technology here in New Zealand?

G: I think probably the one is set up cost of any facility, buildings are expensive if you then equip them to basic microfabrication type standards it becomes very expensive. If you buy equipment then it's even more expensive so yes I think cost is a, cost is one. I think the other one simply is sort of a, probably with many of these products it's a you've got to get into the market first so it's, I guess there's this startup cost vs, it's both a startup cost barrier as well as a market entry barrier which are all difficult. So yeah I guess that's probably the main reasons that I see. It's sort of dual markets slash startup cost

R: Alright. What are the main and potential applications of the work you do? If you can tell us without giving any proprietary information away.

G: So I sort of do, I'm basically a materials scientist. I sort of my interest is in what I guess you can call materials with a little bit of sensing applications but also energy and thermal transfer type applications. So I guess there's a let's call it a microscale energy application is probably where I see the broad area that I would fit in.

R: If you know the answer to this question, how much money does your organization spend yearly on research and development?

G: I have no idea

R: alright do you have and estimation of maybe the percent that they would spend on microfabrication in particular? If you don't you don't have to say anything.

G: No I don't or I can say we probably run our microfabrication facility very much on a shoestring because we've got different users, we'll sort of split costs as best we can, everybody will contribute to the normal running cost. We probably get by with a fraction of the cost what a big facility costs on the other hand I think much of the overhead is already covered by the organization rather than the direct users. So yeah it's a very difficult question.

R: these questions are more to gauge how important is microfabrication to the facility so that we can gauge how to weigh an answer.

G: It's as I say within the university 5 years ago we didn't have a clean room so it's sort of a new facility which to some extent is still growing as we as sort of more people realized they can do useful things there. I believe we sort of are sometimes doing a little bit of work for other people but yeah within the greater scheme of research people use it even within engineering and physics and chemistry it's still a small group of people compared to overall number.

R: Do you know how many people your organization has on staff?

G: I should but I don't

R: That's okay. Do you have an estimation of how many staff they have for microfabrication in particular?

G: I would probably take a guess and say there are probably 5 or 6 academics that are fairly regular users of the facility that would be my best guess. Obviously 5 or 6 academics plus their grad students.

R: Do you have any additional comments you'd like to add because we are coming to the end of our interview.

G: Yeah I think I've probably covered most of it. I think it's a good idea that there's a more concerted effort or at least a giving more awareness of different facilities in New Zealand which I think might well be more that what one might think it is at the moment

R: Can we use your name in association with Victoria University?

G: Yep. What I must probably say is I don't think I'm absolutely the best person to speak to. The person who's actually the lab manager is Natalie Plank who you might well have her name on the list, I think if not I think you should contact her I think she would be the most relevant person at Victoria to speak to. She's currently on maternity leave.

Interviewee: Hamish McGowan

Interviewer: Rachel Ooyama-Searls

Organization: Callaghan Innovation

Location: Gracefield

Date and Time: 19/1/2016 11:30:00

Rachel: For our records, can you please state your name?

Hamish: Hamish McGowan

R: Would you like to remain anonymous?

H: No.

R: Which part of the microfabrication industry are you personally involved in? Supplier, Manufacturer, Research, or Student?

H: Probably Research but the commercial exploitation of research.

R: Which part of the microfabrication industry is your organization involved in? Again, the same 4.

H: Research and the commercial exploitation of that research.

R: What is your job title?

H: Commercialization Manager.

R: In your own words, what is your job description?

H: That's hard. I'm between science and commercial. Helping scientists speak commercial and commercial people understand scientists. So it's about getting technology into the marketplace. Optimizing what scientists do so that it is applicable.

R: What does the word microfabrication mean to you?

H: Very, very small. Small things made for testing, or sensing, or whatever. Manufacture on a small scale. Devices mainly.

R: How does microfabrication play a role in your organization?

H: We have microfabrication skills within our organization. We perceive there is value to be created in New Zealand industry from exploiting and applying microfabrication things and we're trying to achieve that.

R: How do you think miniaturization has changed technology in New Zealand?

H: More online things. You can do things… instead of sending a sample away to a lab and waiting for days or whatever, you can do it in a much shorter, sharper timeline. You can do it in situ where you used to have to take it off-site. You get immediate, fast results. Those sort of things.

R: What do you imagine microfabrication in New Zealand to be like in 5-10 years?

H: I think it will be applied in a lot of different areas especially agro-tech area, agricultural space, I think there will also be some emerging bits and pieces and startups in the medical diagnostics and that sort of areas. And potentially we could have some manufacturers. Sizeable manufacturers. Hopefully only exporting.

R: How do you see ongoing miniaturization affecting the future in 5-10 years?

H: I don't quite understand the question.

R: So like, miniaturization meaning devices getting smaller, technology getting smaller, as it has. Miniaturization would be different than microfabrication because microfabrication has a very specific scale. More like how you think the changing of technology to smaller devices effects New Zealand in the future. Or does it?

H: In some ways, everything is as small as you want it now already. I think the user-centric aspects are going to be interesting in this. Getting the right size of your phone for your pocket. You could make that four times as small. I think we are almost at the stage where things are as small as you want to go. I don't know, I might be wrong.

R: It's your opinion, you can't be wrong in your opinion. How do you think miniaturized technology impacts society in New Zealand?

H: Transportable. You've got it with you, you carry it. There is a lack of constraints. Means you're mobile. Many mobility type things. And immediacy.

R: What would you consider the strengths of the microfabrication industry in New Zealand to be?

H: Some of the staff are absolutely wonderful. Some of them are really, really good. They are very passionate about what they do and they really enjoy it. I think that the openness of our culture is a benefit. People want to work together and increasingly we are seeing entrepreneurism out of our students and early education. People being educated in universities, increasing interest in exploiting technology and starting up companies and things like that.

R: So you would say that the culture in New Zealand is very open to new technologies?

H: Yes, I think so. Good testing environment. It's easy, you can cut off a little segment, a small sector, so you can trial things and try things out pretty fast. And the agricultural sector is quite advanced. Technically large farms, large scale production. Pretty good on those sort of things.

R: What would you say the weakness are for the microfabrication industry in New Zealand?

H: Lack of depth, distribution, it's a long skinny country with not a very big population. We have 5 million people and 9 universities, 7 really, it's not really that sustainable.

R: So really the scale?

H: Scale, yea, and geographical. Small scale, and geographically long skinny country are the main problems I think.

R: What do you know about industry clusters?

H: I think they are good. Success in New Zealand is going to be in exporting. The local market is minor. 5 million people, the bottom end of the world, you aren't going to make a lot of money. You are not going to create a lot of wealth in New Zealand by just being on the local market. We have to export and increasingly it is through collaboration and working together. I think new technologies like this is good for a lot of different players in a lot of niche markets that we can develop things here and optimize and exploit internationally.

R: How aware are you of the microfabrication facilities in New Zealand?

H: Moderately. I know of the one in Gracefield, Andrea and Andrew and Callaghan Innovation. I know about the Photon Factory in Auckland and there are some in Christchurch as well. Canterbury University and there are a few small scale manufacturers near Palliser North. Bits and pieces.

R: How willing would you be to join a cluster initiative for microfabrication?

H: Totally.

R: Can you give us some reasons why?

H: Because I think joining together is the only way to understand what is available and how maybe exploit internationally and all those connections. Because nobody has a scale or context or ability to go out alone. I think working together and collaborating is going to be the way this thing takes off.

R: Do you know any environment concerns with microfabrication?

H: No, not that I'm aware of. I think people talk about nano. There is probably some suggestion of grey goo. That nanotechnology is suggesting. They might get nanotechnology, microfabrication, and microtechnology muddled up.

R: What types of government regulations affect your work if any?

H: None.

R: What is your current approach to stay relevant in this rapidly expanding field?

H: I don't have one, honestly. I'm not technically involved. I'll leave it to other people.

R: Is your company looking to hire more staff?

H: Yes.

R: What factors make it difficult, in your opinion, to compete in a global market?

H: Connections and understanding the marketplace, understanding what is needed and what is possible and then building the connections and what is needed to exploit that. Scale is always a problem. Go from nothing to huge. But I think with microfabrication that might be less of a problem. And our distance from market, our isolation, small economy at the bottom end of the world.

R: How much money does your organization spend yearly on research and development?

H: 25-30 million NZD

R: And how much of that money would you say goes yearly to microfabrication?

H: 1-1.5 million NZD. Not a lot.

R: How many people does your organization have on staff?

H: 400. 180 scientists and researchers.

R: Do you know how many staff are dedicated to microfabrication in particular?

H: 2.5-3. Technologies around microfabrication, 10-15. But the actual microfabrication area in a technical sense. 2.5.

R: Do you have any additional comments?

H: Nope.

Interviewee: Helen Morris

Interviewer: Digital

Organization: Victoria University of Wellington

Location: Digital

Date and Time: 12/2/2016 16:58:14

Question: What is your name?

Helen: Helen Morris

Q: What is the name of your organization?

H: Victoria University

Q: Would you like to remain anonymous?

H: No

Q: Which part of the microfabrication industry are you personally involved in?

H: Student

Q: What part of the microfabrication industry is your organization involved in?

H: Student/Education

Q: What is your job title?

H: Candidate for a Master of Innovation & Commercialization at VUW.

Q: What is your job description?

H: Students of the practice-based MInnComl both lead the development of an innovation project that interests them and work within a multidisciplinary team, consisting of fellow students and other industry partners.

Q: What does the word microfabrication mean to you?

H: The production of miniature structures on a scale from micrometers-mm that are used to collect and process data.

Q: How does microfabrication play a role in your organization?

H: I will be working on a project with Callaghan Innovation to assess what possible projects could be created using the microfabrication technology developed at Callaghan Innovation. This will involve determining the feasibility and need of the product from consumers in New Zealand.

Q: How has miniaturization changed technology in New Zealand?

H: Increased New Zealand's ability to interact with other global countries, having smart phones and access to internet more readily has definitely changed the way people do business in NZ.

Q: What do you imagine microfabrication in New Zealand to be like in 5-10 years?

H: It would great to see it playing a larger role as an alternative energy source and aiding in measuring environmental changes.

Q: How do you see ongoing miniaturization affecting the future in 5-10 years?

H: It seems to be a technology that will increase the lives of people in urban environments first by creating 'smart cities'.

Q: How do you think miniaturized technology impacts society in New Zealand?

H: Positively, adds an industry to NZ's economy that is likely to play a major role in changing the digital industry globally and also nationally.

Q: What are the strengths of the microfabrication industry in New Zealand?

H: Callaghan Innovation trying to set up a network between everyone working in the industry will be very beneficial to all the companies wanting to continue microfab tech in NZ. Specific industries like agriculture will benefit massively from NZ and could aid in the growth of the microfab industry.

Q: What are the weaknesses of the microfabrication industry in New Zealand?

H: Small market competing with globally emerging companies will be a challenge

Q: How do you feel about collaboration with other organizations?

H: It will be essential.

Q: What do you know about industry clusters and how do you see a cluster operating?

H: Clusters are important for companies in an industry to continue innovating and moving on, as each company in a cluster can communicate and continue growing together through collaborative projects.

Q: How aware are you of the microfabrication facilities in New Zealand?

H: As I have just started my project about a week ago, I am only aware of the ones mentioned in your pre-proposal but have had little time to investigate each organization.

Q: How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication field? Why or why not?

H: Very keen, I am only a student at this point, but am keen to play more of a part in the industry in the future.

Q: Are there any environmental concerns with microfabrication and if so, what are they and how are they dealt with?

H: Again not something I've had a chance to look into yet, people will mostly be concerned with waste from production and also whether or not these things will last a long time and can be managed when they are not usable anymore

Q: What types of government regulations affect your work?

H: Again not sure started a week ago.

Q: Are you doing any research in microfabrication? If so, what are the applications of your research?

H: My research will involve looking into possible applications of microfab technology for Callaghan innovation based on current markets and feasibility.

Q: Are you looking to get a job in New Zealand or somewhere else?

H: New Zealand initially

Q: If you are looking to get a job in New Zealand, why?

H: I would like to start my career in NZ then move overseas to increase my skills and travel.

Q: What degree(s) are you pursuing?

H: Master of Innovation and Commercialization (MInnComL)

Q: Do you have any additional comments?

H:

Q: Do you know of other companies or research groups in New Zealand that have interest in microfabrication? Who can we contact and what are your connections with these people?

H:

Interviewee: Iain Hosie

Interviewer: Rachel Ooyama-Searls

Organization: Revolution Fibres Ltd

Location: Auckland

Date and Time: 26/1/2016 12:00:00

Rachel: For our records can you please state your name?

Iain: Iain Hosie.

R: And the name of your organization?

I: Revolution Fibres Limited. I'm the managing director.

R: Which part of the microfabrication industry are you personally involved in: supplier, manufacturer, research or student?

I: We are manufacturers and research as well so we run essentially manufacture of nanofiber but more often than not there's a huge amount of product development that has to go on before the manufacture and so we offer that as a customization service as well. So it's paid research and we're sort of recognized in New Zealand as advanced materials specialists. Our specialty is nanofiber but we have quite a broad understanding of all chemistries.

R: What part of the microfabrication industry is your organization involved in? Again the same four options. Manufacturing and research?

I: Yes.

R: Can you state your job title?

I: Managing Director and Founder.

R: In your own words can you give us a job description?

I: Yeah so, I'm essentially the CEO. I handle the marketing and business development side, I run the technical team, research and development team, and also I'm on the board of directors as well so strategy and internationalization of the business.

R: What does the word microfabrication mean to you?

I: Yeah that's interesting so, I see it in two ways. So it could be a cluster of businesses that have complementary skills that allow greater things to happen in manufacture but also, I see microfabrication as potentially making miniature parts as well. So I don't really know which kind of angle you guys look at it in a sense.

John: I think for us it's more of microfabrication is the making of small parts. The cluster is kind of the organizations working together.

I: Organizations working together. Yeah so yeah microfabrication. We essentially are making nano textiles basically in the micron width and thickness. So we've looked at the nonwoven industry sector and started to look at the properties that we can achieve by bringing textiles down to that kind of level. So we are right into that microfabrication kind of space.

R: So how does microfabrication play a role in your organization?

I: It's essentially what we make. So if you think about textiles, many, many materials have gotten smaller and smaller especially the metals and alloys and things like that, but textiles have been quite slow to follow suit. So I think what we're now seeing is we're looking for performance advantages and smaller parts, textiles have been quite slow to follow suit but through our technology, through electrospinning, you can make very, very fine but huge surface area textiles. So yeah it's pretty much the game we're playing in, in multiple industries. So we are looking at it from electronics to medical textiles to filtration and all sorts.

R: In your opinion, how has miniaturization changed technology in New Zealand?

I: I think for us we're seeing, for our business this technology has allowed us to create textiles from materials that previously couldn't be a textile. So you know a whole bunch of biopolymers that would not withstand the usual fiber manufacturing techniques which involves basically melting polymers. We do everything at room temperature so we can suddenly start to use materials that previously couldn't be textiles. It's really, really cost effective. One kg of polymer can make a fiber that would reach the sun because it's so fine. So we've got really, really unique materials that probably wouldn't ever compete in the macro textile world because of the cost of them, all of a sudden being turned into high value goods. We've also done a lot of work in making nanomaterials easier to use in the form of a fabric. So nanoparticles and the like nanotubes are very, very difficult to handle and very hard to get into other people's manufacturing processes, but in the form of a textile they're much easier to use and much safer as well to use. So that's where we see the opportunity and we're seeing it work, we're seeing it being adopted in New Zealand.

R: What do you imagine microfabrication in New Zealand to be like in in 5 to 10 years?

I: I think we will specialize in unique materials, bio-based materials probably. I think we've made a good start in nanofiber and I think because of our manufacturing capability we are one of the leaders in the world in this space. A lot of our research is now directing through our company. So I think we'll see a lot more nanofiber production and applications. That's exciting. So I think New Zealand will be similar to the Czech Republic and Korea where people start to look towards us as people who develop nano textiles and micro textiles. We're working on a whole lot of functional nanomaterials as well in New Zealand that I think are going to -- I don't think we'll ever going to be a commodity player. So I don't think we will ever do titanium, zinc kind of nanoparticles but we are working in New Zealand on a lot of functional things like MIPs which are molecular imprinted polymers and MOFs which are metal organic frameworks and I think a lot of that kind of work is going to come to fruition as well, but New Zealand will probably play a specialist role. We’re not going to be big manufacturers.

R: And how do you see ongoing miniaturization of technology affecting the future in 5-10 years?

I: I think as people start to understand-- at the moment people just want devices to be smaller and they want materials to be smaller without a clear understanding of what the advantages are apart from small. I think the research which is happening now and actually seeing the performance advantages over miniaturization is really going to, people will see the point a lot more. So I think at the moment the people who are using it are the real innovators. Pretty soon you’ll see, if you like, the bigger followers who have let the innovators make all the mistakes will start to come and see the benefits a lot more. I think it's still going to take another five years to take a step out of the research space and into true adoption though.

R: How do you think miniaturized technology impacts society in New Zealand, if at all?

I: I there is just a complete lack of understanding of it. So there is still fear. We’re probably one of the biggest sunscreen users in the world though, so you know we use nanotech and miniature technologies without really understanding it. But we’re quite big in agriculture and I think that that sector is starting to see real benefits in it. So that really affects New Zealand if we could, if the dairy and agriculture sectors could pick it up they could use pesticides safer or we can use it to functionalize food groups. Because the industry is so big in New Zealand it affects 25% of our economy. It's just milk. So we can improve milk products and the like with functional food additives and things like that. It makes a huge benefit to the economy. I hope that it brings safer goods, more functional foods and better materials.

R: In your opinion, what are the strengths of the microfabrication industry here in New Zealand?

I: I think we’ve got a strong research sector. So there is a lot of good research happening. There's still a very poor link between researchers and industry. And part of the reason is there’s not many companies in New Zealand doing microfabrication so the research seems to just stop, a couple papers get published, a patent, and nothing else happens. We’re very strong in research; we’re very poor in commercialization. And we also have some quite unique materials which I think haven’t really been explored to the depth that they could do and to actually deliver some really unique products as well. So we’re working on carbon nanofibers from a natural source which has huge advantages over nanotubes and the like. But it takes time to actually characterize them and compare them to existing technologies and then upscale them as well. So we're really good at innovating. I think we need international help to commercialize.

R: This question might be a little redundant but what do you consider the weaknesses of the microfabrication industry here in New Zealand?

I: Yeah I guess I kind of answered that in the last question, yeah. The strengths are the innovation; the weakness is the commercialization and partnerships and also getting noticed. So I find in New Zealand, we potentially publish research to get noticed rather than have strategic commercial conversations with businesses and that sometimes puts us on the back foot. We just basically disclose pretty revolutionary stuff which might be better off being talked to a project manager or CTO rather than putting it in an academic journal. So that's why we tend to just get stuck in the research kind of trap if you like.

R: How do you feel about collaboration with other organizations?

I: That's critical and it's our strength. When you look at our brochure, our whole business model is pretty much summarized through partnerships. Nanofiber is a platform technology so it can be used in so many industries, it's quite ridiculous. A lot of the advice we got early on was, "stick to one or two sectors" but as the inquiries kept coming we realized that it shouldn't matter what industry we're talking to. As long as you can create a good partnership with the interested party, we can develop the textile for them. So we have to have a clear understanding of what they want versus what we think they want. So we take the technology to a point, we do some characterization and some prototyping to try and get the interest of a partner and then we do the true product development with the partner. So collaboration is really critical. I think also we want to collaborate with research institutes overseas a lot more because there seems to be a greater link to industry. So our research institutes are not well linked to industry so everything we do with them seems to be for an academic purpose, not an industrial purpose. So that's what we're trying to find is our collaborative hubs that we can be part of that are very well connected to industries. So I've got a person in North Carolina now working with the North Carolina Government to try and get us to be part of the textiles movement in North Carolina, for example. Because it's just a good sector and the strongest sector in America for textiles.

R: What do you know about industry clusters and how do you see a cluster operating?

I: I think clusters, I’ve seen them, I’ve been involved in them. I think so far they’ve been very cumbersome, everyone’s got their own self-interests, and quite often if an opportunity comes to a cluster it seems to be a battle to take ownership and nobody is truly collaborating. The ones I’ve seen work well there’s almost a coordinator or a team of experts who pretty much are an arm’s length between the client and the cluster. So there’s almost like a mediator in the middle who decides who gets the job. When they come to the group as a whole it never seems to work. It seems to create-- everyone seems to think that they can play the lead role type thing. And I think it might be because no one has a clear understanding of how everyone fits in the cluster. So I haven't seen it work too well. But in my travels I've been to San Francisco and Los Angeles and now in North Carolina we're looking at these clusters because we actually see a lot of, for a small company in New Zealand, we see a lot of benefits in getting into I guess what they call innovation hubs, where people from multiple industries are sharing spaces and sharing resources and collaborating just by the nature of being close to each other. And we really like that kind of concept and we see that the IT industry has done it really really well. And so many good ideas have just spun out of lunch rooms because people were just collaborating. And I think microfabrication needs to take that same approach because I know that just in my business having a chemist sitting beside an engineer creates wonderful things. Whereas if you have and engineering company and a chemical company they'd never meet. You need to get that whole multidisciplinary kind of thing happening. But company to company it’s hard; it’s more person to person.

J: So would you say a network of relationships would be better than a cluster?

I: I think a physical cluster would work better than a network and I think if you have a network then it would need a mediator. So almost like the client is paying the mediator to find the company for them.

R: Kind of like a travel agent?

I: Kind of like a travel agent, yeah. We’ve been pitched a couple of times from some companies doing this kind of global network structure, but I don’t think big companies are quite using them just yet. I think it’s still a bit of a free for all.

R: How aware are you of the microfabrication facilities in New Zealand?

I: Quite aware. So Callaghan Innovation, I’m sure you’ve heard of, have a list of the services and the like. And we’ve been trying to get a huge amount of characterization done on their fibers in the last year. And so we’ve gone to talk to a lot of people. The only issue is, it’s really hard to get in to actually do the testing because people haven't got a services setup like we have. It's very much research institutes' equipment, they don't really even know how to charge it out. For some universities, if you use their equipment, they want to own the IP so you can't use their equipment because you really just can't hand over IP just for - and these huge waiting lists, waiting times. And they also don't want you to use their equipment, they want them to use it themselves, which in some cases is fine. But if you don't have a system...so for example, we're making acoustic textiles, so we want to find out not what it's doing in a piece of building material which anyone can test. We want to know what would it be like in the hearing aid. Can we stop those annoying frequencies? But there is the equipment there. But oh no, no, we don't use it for that. So there's a lot of roadblocks because a lot of this equipment's owned by one person. They got the machine for a certain reason and they don't really like to push the boundaries of the machines. So I think that's the main problem: we know the equipment's out there; it's hard to use though. So quite often we have to beg, borrow, steal, all sorts of stuff to just try and get a quick and dirty test done

R: How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication field? And why or why not?

I: Would they be New Zealand companies?

R: Yeah, New Zealand.

I: Yeah, of course we'd be interested. I'd be a little skeptical it would work because we've - have you seen Product Accelerator and things like that? Yeah, I don't know. We seem to sometimes feel like we're a bit of a lone wolf in New Zealand. We've embraced partnerships I think. In the science sector, in microengineering sector in New Zealand, not a lot of people have made that mental leap into open sharing, collaborative ventures. I just think that there needs to be greater embracing. We would be fine; I'd be right into it. I just wonder if domestically we've really turned that mental switch yet into collaboration.

R: Switching gears here, are there any environmental concerns with microfabrication? And if so, what are they and how do you deal with them?

I: For us, the concerns are we use nasty solvents. They're not toxic, you know they're acids. So I guess it's more personal worker safety is our biggest focus and concern. Safety of the materials. We have been working with graphene and carbon nanotubes so we're a little cautious of the use of what I would call more the ceramic materials, hard nanotech. We're making polymer fibers, so we're not worried about our fibers at all. They're made of non-hazardous polymers. They stick together really well and even if they get inhaled, which is about the only way you could get exposed, they're not hazardous; they'll break down in the body. But when we use nanosilver for antibacterial properties, where we still haven't commercialized it because of - I wouldn't say safety concerns, I would say more like regulatory concerns. I think we're pretty comfortable and safe, but we're not comfortable that the regulators would feel the same way. So there's a lot of hurdles, and that makes the commercialization pathway pretty long.

R: What types of government regulations affect your work?

I: Okay, well the HAZNO Act. So the Hazardous Substances and New Organisms Act is our main one. That's just telling us how we should be handling chemicals in the business. And if we ever release products in New Zealand, finished products, some of them could be subject to the HAZNO Act as well, but we're not really making those types of products. Most of our products go overseas. So it's more the overseas regulations that we need to be more aware of. So most of our products that we're making right now are not really going to be too worried about. But the Health and Safety Act, which again is worker safety. And we're also AS9100 certified, so we're supplying nanofiber into the aerospace industries. So for us, that's way more in depth than any government regulations. We've got a lot of quality assurance parameters that we have to stick to which are quite brutal. So if we stick to AS9100, we pretty much comply with everything, so we use that as our framework.

R: So here we're switching to specialized questions now, so it might get a little redundant. What are the main applications of your work?

I: So I guess what we create are functional textiles. We have them in air filtration so we make those filters here which go into ventilation systems, residential. We're partnered with a US firm to make facemasks. These facemasks here are made in the US, but the nanofiber's made here. We have anti-allergy bedding, so that's really keeping dust mites and bedbugs out of pillows and things. Nanodream, that one there. That's sold in New Zealand and Australia in a few specialist stores and pharmacies and the like. We have Xantulayr which is a composite reinforcement product that's our strongest growing product. So that's used to toughen resin. And we have an acoustic line as well, so that's using ultrathin nanofibers to try and get the acoustic performance of reasonably thick bats and foams and things. But I guess we're also talking to clothing companies, we're looking at energy storage, we're looking at conductive fabrics, so that's a lot of the research that we're doing with partners working towards hopefully some commercial products in the next one to two years.

R: What is your current approach to stay relevant in the rapidly expanding field of microfabrication?

I: A lot of market research. We do a lot of market research. We read a lot of journals. We innovate ourselves; we're really trying to blend chemistry and engineering to try and get those kind of sparks so our whole business is running on three silos which is safety, speed, and diversity. And the focus of R&D is always generated towards that so it's using safer polymers or solvents. That's more for our worker safety and the like, but also speed. So we're looking at the textiles industry and saying, "Well, that really boomed when you could make lots of it." So that's what we're spending a lot of our time on is trying to have good techniques so that we can get the price down and the volumes up. But we don't really want to be a commodity player either, so our business is going to stay in that niche manufacturing, but we need to know it can be manufactured at an industrial scale because significant partners need to get to that level and we would help them get to that level as well. We would design the machines and put them in place. Yeah, so I guess what we've created is a business model which has three pillars: manufacturing, which is like the bread and butter, products (that we make our own products and sell them), and the other pillar is customization or the operation on it, which is essentially non-recurring engineering, which is when we're designing fabrics for specialist applications. And at the moment, 60% of our revenue is manufacturing, saying about two years, three years, 60% will be the non-recurring engineering. And it's going to form quite a big pipeline of not just products but intellectual property.

R: If you're comfortable answering this question, how much money does your company spend yearly on Research and Development?

I: Roughly 300 thousand.

R: And then how much money does your organization spend yearly in microfabrication in particular for Research and Development?

I: All 300 thousand. It's just what we do.

R: How many people does your organization have on staff?

I: We have ten and we'll have twelve as of March. So twelve people.

R: Then how many people does your organization have on staff specifically for microfabrication?

I: Essentially nine.

R: And is your company looking to hire more staff?

I: Yes, so we have three new positions this year. So essentially that's a 30% increase.

R: How do international trends shape the future of New Zealand microfabrication?

I: Well, miniaturization is happening. It's alive and well. I don't think a lot of the manufacture happens in New Zealand, so we have to find the right place in the supply chain for ourselves. I think there is a trend towards open innovation, so that means essentially companies are looking at specialists in certain fields rather than becoming specialists themselves. I think that's a promising movement for New Zealand because we do have specialists who are struggling to get into bigger companies but now the big companies are not trying to become experts. They're almost downsizing the R&D and contracting out. So I think that's good for New Zealand. I think we need to promote it better because that's what countries like Finland and Belgium have done really well. They've seen the demise of some of their economies, but they've gone and re-promoted their expertise. And so essentially the firms are making good wages by working with larger firms and just subcontracting the R&D, so I think that's what New Zealand needs to do. Yeah we've got to stop going at it alone, it never works. So a lot of New Zealand firms have great ideas, great intellectual property but just the cost of going international is far too great and they don't have the capital here to do it.

R: What factors do you think make it difficult to compete in a global market?

I: For New Zealand companies, it's the cost of getting noticed. You notice yourself from a long way away. I think it's what we call the tyranny of distance. Different time zones makes it very difficult to gauge with companies. No one comes here. We always have to travel; we're always the ones who are hopping on the plane. I've had one client visit me in five years and we've had to go overseas the whole time. And I think also that it takes a long time to get past the curiosity banner. So it takes some companies and some countries a long time to get over the fact that they don't believe this kind of innovation is happening in New Zealand. They think it's -

R: They underestimate New Zealand.

I: They underestimate it and I feel we have to prove ourselves well and above other companies. And a lot of New Zealand businesses are startups, so we don't have the trading history that some companies will look at as a way of making a decision on who they work with. They want to see, "who else do you work with," you know? They don't want to be a first. And for us there's a business, we're only six years old but in the last couple of years we've found that it's been a bit of a hurdle, is that people just want to see who you've worked with before and when you're just starting out, that makes it really hard to get your first couple of clients.

R: So that's sort of the end of our interview, but do you have any additional comments you'd like to make?

I: No…. I know it's been talked about a lot in New Zealand, specialist clusters. I sound perhaps a little pessimistic maybe. Because really I'm optimistic about the idea, I'm just a little pessimistic about our ability to pull it off in the near future. But we're keen.

R: Do you know of any other companies in New Zealand that might have interest in microfabrication that could help us in our project that we could contact?

I: You might want to talk to Kode Biotech; they're mostly medical. They basically make functional surface coatings that can be used as reagents or antiviral, antibacterial kind of coatings and they stick to any surface. So it's cool. What else have we got? I also run a nano business which is called (...) which is nanocoatings, so developing silica-based nanocoatings to stop mostly water from beading on - but you'd pretty much hear the same answers if you interviewed me again. Yeah I'm just trying to think, not really. I'm sure you've been given a good list Callaghan. I mean, there's the guys who do all the liquid crystal kind of stuff like Rakon. It's not huge now, well there's lots of people getting in and dabbling and stuff like that. Rakon are well established, but they boomed and busted a little bit there. They're sort of trying to regrow, so they've had an interesting story.

Interviewee: Jerome Leveneur

Interviewer: Rachel Ooyama-Searls

Organization: GNS Ltd

Location: Wellington

Date and Time: 20/1/2016 11:00:00

Rachel: For our records, can you state your name?

Jerome: Jerome Leveneur.

R: And can you tell us the name of your organization?

J: Institute of Geological and Nuclear Science, short for GNS Limited.

R: Would you like to remain anonymous?

J: No.

R: Awesome. Thanks. Which part of the microfabrication industry are you personally involved in? Supplier, manufacturer, research, or student?

J: Research.

R: What part of the microfabrication industry is your organization involved in? Again, the four, same four.

J: Research and we do (…) supply some Ph.D. students.

R: What is your job title?

J: Material Science and research. No no, Material. Material Science and innovation. No, Material Research and Innovation Scientist or something like that.

R: In your own words, can you give a job description?

J: Applying for funding. No, I am, some scientist am a scientist is an, ahh. So we got, in GNS we got scientist, senior scientist, principle scientist. I am scientist. I am doing experimentation and that is this, and also connection with end users, which in our case are mostly industry, so, and that is in the domain of material science. I am guessing one of the next questions is going to be about what we do, but.

R: Well, the next is actually what does the word microfabrication mean to you?

J: The set of techniques and methods to be able to engineer devices at the micro- and nanometer scale.

R: How does microfabrication play a role in your organization?

J: We set a little bit here upstream to get into fully microfabricated devices, so we, on one hand are looking at new materials, which we hope we can then implement into devices, and when we get to that implementation stage, then we need to do, to look into collaborations around to be able to get to devices. So we have been doing that in the past. We've had some, ah, a few works about doing business in photolithography, and so, but mostly materials.

R: Mostly materials that you would then use in microfabricated devices?

J: Yes, so, we are using, we have techniques such as ion implantation, ah, different type of implementation systems and ion beams (…) And then we have also different (…) processes, so, sometimes we, so, those processes, those processes individually are part of microfabrication, (…), etc., but in our case we would just be looking at one or two of these steps combined and not the full set of, ah, that are usually involved in a microfabricated prototype or device.

R: In your opinion, how has miniaturization changed technology in New Zealand?

J: Oh, I guess the thing that, to my understanding, the, ah, New Zealand microfabrication-related industry is not, not, not there, not set up yet. So, a lot of views of all microelectronics industry, so of course lots of cheap, they use up all of the development overseas is being applied here, and also lot of fundamental research materials research is sent overseas to do the devices, but very little is, to my understanding is done in New Zealand, and

R: Okay, uh, what do you imagine microfabrication in New Zealand to be like in the next 5-10 years?

J: If it could be produced by cows, we would be doing it.

R: It was a good answer.

J: But no, the, as far as we are seeing the development there, a lot of integration of overseas technology is still going to go strong, so we are going to have lots of needs of microelectronics. The techniques that are related to miniaturization of ah, of ah PCB-based electronics is playing a big role and that is where microelectronics is starting to slowly emerge. Can do smaller and smaller PCB multiple layer with smart techniques that have been, that are coming from the microelectronics. That is likely to be impacting New Zealand because we have lots of, um, device manufacturer, but not cheap manufacture ah, per say, but I guess that's, the impact for the near, in the future is not so much probably, there would be foundry all-out microfabrication lab, ah, industries in New Zealand that we can foresee. Labs that can change the universities are more likely to uptake and increase their facilities because they need to keep up with the speed of the rest of the world. If it happens that something is discovered in those universities important enough to motivate the formation of, there is a creation of big semiconductor industry in New Zealand then there will be, then there will be interest in, without the business case, it would be the dairy industry in New Zealand.

Tyler: So, you mentioned PCB. What is that?

J: Ah, What does it stand for? Circuit board, printed circuit board. There we go, printed circuit board. So, you know the green stuff?

T: Yeah, yeah,

J: Green chemical resistor, so we do that here. There are plenty of companies in New Zealand that are printing that.

R: How do you see ongoing miniaturization affecting the future in 5-10 years? I guess you kind of addressed that in the last one, but.

J: Well, in, that was New Zealand, for the rest of the world, it's ah, it is still going to go, ah, go strong and hard. It is also going to depend on whether the investments are going to keep up with technology development. But yes, it should be better for New Zealand. Better (…) in the world.

R: How do you think miniaturized technology has impacted society in New Zealand, if at all?

J: Oh, now it changed, ah, I think it changed a lot and mostly related to the application that was enabled by microelectronics: phones, computers, and nowadays: drones. Multiple application.

R: Sort of shifting gears here. What do you think the strengths of the microfabrication industry are in New Zealand?

J: Material science, we got a very good, some very good teams around material science ranging from all the way from physical to chemistry. We got some excellent labs, looking at photo, ah, laser-based microfabrication (…) in Auckland. And we've got good labs around, scattered around, working, doing some microfabrication and providing good prototype devices for their own institution, or universities.

R: What do you feel the weaknesses of the microfabrication industry are in New Zealand?

J: One big weakness is that there is no connection between industries because there is no search (…) in New Zealand. So, they can find of slightly disconnected from the market, but again there is possibilities to do all the job overseas, and then I don't think in the microfabrication lab has a

100% knowledge of what next-door is doing. So, the integration of what the capabilities of those labs connected to the other material science lab, could be (…) probed.

R: So, communication problems?

J: Yeah, communication, funding, ah, politics.

R: How do you feel about collaboration with other organizations?

J: We try to do it as much as we can. Very much encouraged, in a sense and a cause of funding, but it's a three (…) where the, well, we aren't rushed to collaborate. There is only so much money available. So, in terms of playing together for research funding, we can't collaborate as much as we could. And then each institute would have different. So, there is on one hand a big push for collaboration, and on the other hand a system that is not necessary encouraging it.

R: So, a system that does not support that kind of thing?

J: Yeah.

R: So, what do you know about industry clusters and how do you see a cluster operating?

J: Ah, we are a part of two major clusters here. We got MacDiarmid Institute for Advanced Materials (…) Technology and we are a part of the particle acceleration. So, these are two quite different beasts. One is looking at materials science and the application of such (…). So, probably in every lab doing microfabrication or material science related, you will have someone from MacDiarmid in New Zealand. So, its small, very small on the research side providing support for the science community to get together and share, and on the other side, the particle accelerator is consortium of universities and CRIs (Crown Research Institutions) which ah, which aim in answering the needs from New Zealand industries. So, basically becoming the first port-of-call when someone has a complex R&D problem that they cannot solve in-house. So, from these two examples of clusters that we, that we are a part of. So, basically, in creating, so on that, having support on organizing workshops and meetings to have people share ideas, and ah, (…) the ideas in a way that everybody can be sure of what can be done and create for the new work and collaboration.

R: Are you aware of the microfabrication facilities in New Zealand?

J: I am aware of a few. I am not sure of all of them.

R: How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication field, and why or why not?

J: Oh, I would be very interested. Because, ah, that would allow us to get a better streamline, pathway to market for some of our technologies, while mostly methods and processes that we have, which could be applied to the microfabrication, in the microfabrication realm. It would be very beneficial if we could, ah, access. I mean, have a better picture understanding what people are doing and sharing.

R: Are there any environmental concerns with microfabrication that you know of? And if so, what are they? And how do you deal with them?

J: Ah, There are environmental concerns around all the hazards related to chemicals, specifically used in the, in some microfabrication process, but my understanding it's very well dealt with in New Zealand. (…) Hazards regulations, so, there is very little chance that a big accident would happen, but again, there is no big industry to do such jobs, so, in effect of scale I guess if there is enough people doing it, you increase the risk of having a, of problems happening. The risk (…). The risk related to nanostructure materials, mostly from powders and dispersions is yet to be accessed, and that is becoming effective problems, or related to that, then future microfabrication plans may have issues operating well, would have to have to which to enforce stronger mechanism to prevent release of nanostructure materials in the environment. That is not regulated, and not known yet. The next big thing.

T: So, is that like something that's like a new thing that just, powders and

R: Like nanopowders?

J: Well yeah, it's not new. I mean, zinc, (…), titanium particle is being, are being used in creams and food for 3 decades now? But they are slowly, there are some debates around the impact around nanoparticles being released in the environment. So, if future microfabrication processes rely a lot on fabrication of disperse of powders, then the risk, if there is any, will be a problem.

R: And what types of government regulations affect your work, if any?

J: We ah, so we have supple (…) less usual for New Zealand. We are working a lot with ionizing, no, devices producing ionizing radiation. So, we are, one of our regulations (…) is radiation protection act in New Zealand, which basically follows the guidelines for my (…) to the letter. Regulations around chemical and (…) and the rest of the environment. Regulations around health and safety has become a lot stronger, starting on this January? Or was it last July? Whatever.

Recent change that typed into law (…) yeah, first of January. Effective first of January. That is changing the regulation around who is liable for what in the companies. What else are we, ah, information act. We are part of a current research institute, so, we have a duty to provide as much as we can, information available to the big, to the extent where we, it doesn't compete with our need to provide, to remain profitable and everything commercializable, IP will be separate. We will be kept protected of course. Apart from that, yeah, I don't see anything else.

R: Okay, thank you. So, now we have some research specific questions. What is your current approach to stay relevant in this rapidly expanding field of microfabrication?

J: As I said, I have put a lens, a very focused lens on materials science, so, new materials, new functions of materials, with they are topographical (…) to the systems (…) systems both magnetic and theoretic materials. So, their ability of all those new, to produce all the new materials and being able to shape them to (…) in the proper geometry and properties suitable for microelectronics. These are what I think driving a lot developments.

R: Is your organization looking to hire more staff?

J: I wish.

R: So no?

J: No. I am part of a very small team within the general science. General science of all these, mostly related to earth science from earthquake, tsunamis, (…) to it, to understanding the geology and common water and the use of resources, whether they are minerals or common water around New Zealand. So, we are much focused on the material science suspect end to while (…) And we are about 15 out of 400 to that, so, very locally, knows it, it is unlikely there will be hiring, for the rest of general science there will be hiring.

R: So, how much money does your organization spend yearly on research and development, if you know?

J: Ah, I would put you to (…) the annual report, which is available on the internet. I forgot the figures. You can grab a copy of the way out.

R: What factors, in your opinion, make it difficult to compete in a global market?

J: Ah, It depends on which aspect again. If it's, we're looking at anything in industrialization, it is a lack of strong manufacturing or microelectronics industry. If it's science (…), we are actually doing pretty well. So, distance used to be a problem. I don't think it's really a problem anymore.

Transport is easy and communication goes without much problem. It's really more related about no end users to the technologies, nobody to take the technologies, and particular choices around what, where their money should be put for what first.

R: So, who gets funding?

J: Oh yes, funding. What gets funding first. So, (…) choice unique, well, less and less unique for New Zealand. Still very unique for New Zealand now so.

R: Gotcha.

J: It's good for some fields, it's less good for some.

R: It's good for maybe dairy?

J: Well, yes. It's slowly changing. But yes, diary is still.

R: I am sorry. You answered some of these questions in a different question. So, I don't want to ask you the same ones. What are the main and potential applications of your work?

J: Ah, we are doing mostly coatings and sensors, but the applications of it are really dependent on which company will be helping, and we have been having involvement from manufacturing, in food processing, or appliances, without giving, (…) anything real key example, but that is the type of companies that we are working with, and we will also be looking at sensors in the security system, in the security field. So, applications are really, whoever needs us, we will find the (…) for as long as it is based on material science, mostly surfaces and coatings, and sensors, and sensor systems. We can provide a solution for that. As well develop for that.

R: Do you have any additional comments? We are coming to the end of our interview, so, if you have anything else you would like to add.

J: No, just if you can send whatever is going to be public before it gets public, so that we have the final. That would be great.

R: Is it alright to use your name in association with your company, or would you just like that to be separate?

J: No no no, that's fine.

Interviewee: John Newton

Interviewer: William Boyd

Organization: Pure Depth Incorporated

Location: Auckland

Date and Time: 26/1/2016 10:00:00

William: What is your name?

John: John Newton.

W: What is the name of your organization?

J: This organization is called Pure Depth Incorporated.

W: Thank you. Would you like to remain anonymous?

J: No, it's fine. But I can also speak for a couple of other companies too, Stretch Sense which I'm the director of. Are you going to talk to Stretch Sense?

W: We're going to talk to Stretch Sense.

J: Ah, good.

W: What part of the microfabrication industry are you personally involved in?

J: So we do microlithography so we spin coach wafers and then make holographic interference devices, you know, diffractive optical elements, DOEs, so we do those for prototyping, testing out diffusers. So minimum etch size there is only a couple of micron. Potentially there is potential to go under nano type stuff but that's really hard.

W: So would you consider yourself a supplier, a manufacturer, researcher, or student?

J: Just a researcher really.

W: And what part of the microfabrication industry is your organization involved in? Given supplier, manufacturer, researcher, or student?

J: We have someone contract to us to make our devices but we do the research so kinda research and then customer, I suppose.

W: What is your job title?

J: I'm an Engineer, that's all.

W: What does the word microfabrication mean to you?

J: Many things. Could be self-assembly like I was involved with touch screens with a previous business and they were self-assembling, you know, sort of nanowire technology so that could be one. Or it could be just making things on a small scale. Using often lithographic techniques. So that's really most of it to me. So you're talking about micro and not nano right?

W: Both.

J: Nano is a totally different ballgame. I've got no idea.

W: How does microfabrication play a role in your organization?

J: It plays a role because we use it to make light diffracting or refracting optical elements. So the fabrication is really lithographic and then casting and etching and molding. So usually just 2D structures with very small but precise z axis, you know, for optical interference with ices.

W: How has miniaturization changed technology in New Zealand?

J: How has it changed technology? I know that in the agricultural sciences, it's fairly important for cell sorting and all that stuff where predominantly an agricultural commodity kind of product so there are projects to sort. For instance, animal sperm into a single sex, for instance. Which I know a few of the individuals involved in that project which you might talk to at the microfab lab. Cather Simpson, for instance. So there are possibilities there which could cut down the cold rate of bobby calves for instance or make the dairy industry a bit more productive. So potentially there is quite a lot in the agricultural side.

W: Thank you. What do you imagine microfabrication in New Zealand to be like in 5-10 years?

J: I haven't really thought about it. We tend to be followers I suppose. So as the devices come out, it becomes more feasible. Potentially 3D printing can be a factor there too with 3D micro devices.

W: How do you see ongoing miniaturization affecting the future in 5-10 years?

J: Well potentially who knows? Hopefully most of its good but you know it will enable, potentially it will enable things which are just not possible now. Or are possible but cost too much.

W: How do you think miniaturized technology impacts society in New Zealand?

J: Impacts society? There is a bit of fear, I suppose. Fear of nanoparticles but probably not much effect in the next 10 years hopefully. I think we should move quite slowly on the nano side of things, you know. Microtechnology is already here and now with DLPs and electronics. So nanofabrication is already like 15 nanometer semiconductors so it really is affecting our life and potentially it could be catastrophic, you know as we move into 3D electronic devices. Perhaps you could get computing power that exceeds ours. It could be quite catastrophic or it could be very good. Something society has to look out for.

W: In your opinion, what are some of the strengths of the microfabrication industry in New Zealand?

J: It's a fairly open environment so it's pretty easy to get things from the US for instance. So the strength is that we aren't really that far away. I can pick up phone and talk to anyone. Like at the moment, New York, Rochester's only 4 hours difference. So that's pretty good. Someone's good for us. Like in the winter it's 8 hours or 9 hours or 10 hours so that gets a bit more difficult but it's easy, you know. And you can have things here in 3 days, not bad. Just shipping is a bit of a problem, that's all. A bit more expensive. Biggest thing for us is actually shipping, government should organize a better shipping system you know. Because we are at the mercy of FedEx and DHL and NZ Post and stuff.

W: Apart from the cost of shipping, what are some of the weaknesses of the microfabrication industry in New Zealand?

J: There isn't a cluster so there's no real expertise to draw on so you kind of tend to operate alone. And travel is expensive so it's hard to get, it's easy to pick up the phone but then it's good to meet people as well. So there's no real expertise here. So it's quite weak as expertise, knowledge.

W: How do you feel about collaboration with other organizations?

J: We have to. That's no problem at all, that's the only way forward.

W: What do you know about industry clusters?

J: They tend to happen naturally and they can be helped by government intervention as well and clusters tend to happen because it gives you a good job pool and knowledge base and the universities can kind of help as well with courses and student placement so it's certainly a virtuous circle, you know. It's certainly a good thing. Not many clusters here but probably is a good idea.

W: How aware are you of the microfabrication facilities in New Zealand?

J: Not really that aware because I've just been concerned with the optical side of things. And I know that 2, possibly 3 of the universities have kind of smallish programs. Not really that well-funded. We make use of the local one here in Auckland, microfab lab but that's for lithographic and spin coating and stuff. What was the question again?

W: How aware are you of the microfabrication facilities in New Zealand?

J: Pretty much as far as the lithographic side of things goes, yea.

W: Alright, thank you. How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication field?

J: Very much.

W: Can you give any reasons why?

J: Just to help the industry and help us as well. It's a virtuous circle, you know. It gives us ideas and we can help each other so it's a good thing to do.

W: Are there any environmental concerns with microfabrication?

J: Not with micro really, certainly with nano there appears to be.

W: Alright. And what types of government regulations affect your work?

J: Just environmental waste disposal with chemicals and to a certain extent fumes. That's it but that's easy to there are chemical disposal companies that will recycle your chemicals or burn them or whatever they do.

W: What is your current approach to stay relevant in this rapidly expanding field?

J: The current approach? We have certain problems to solve so we just kinda find suppliers and get on the phone and email and visit so we try and leverage as much help as we can. University or universities anywhere in the world really. The industry tends to be very helpful actually.

W: Is your organization looking to hire more staff?

J: That's undergoing changes at the moment so not at the moment but potentially later on.

W: What factors make it difficult to compete in a global market?

J: Which factors? Its lots of competition and you have to know the customer problems and customer demand. It's just business, you know. There is a lot of competition and you have to have good product. And you also have to have good markets and you've got to get your cash. Cash possession, right. So for a small company it's quite difficult for

W: What are the main and potential applications of your work?

J: Our work is just for display industry and the biggest market for us is going to be automotive clusters. Gauges.

W: How much money does your organization spend yearly on research and development?

J: [redacted] there's roughly 10, 15 employees including contractors and so

W: How much money does your organization spend yearly on microfabrication in particular?

J: Probably one and a half full time people. [redacted]

W: Thank you, how many people does your organization have on staff?

J: Roughly 8-10. It varies.

W: And how many people does your organization have on staff for microfabrication?

J: Just one and a half. Because I'm a half time employee.

W: Thank you. So we just have a few more questions. Do you have any additional comments that you would like to add?

J: It would be, the first thing, like subject. Especially self-assembling systems because when you're talking about microfabrication, there is a lot of fabrication to do because you tend to have little devices that replicate, that repeat the operation I suppose. And so some sort of self-assembly would be very interesting for mechanical devices or even for electronic devices. Kinda interest to see that you know, do some work with touch screens that try and achieve that with crystallizing nanowires and so forth. So it would be very interesting to have some institute that some research organization that concentrated on that side of things too.

W: Do you wanna work with that sort of stuff personally or are you just interested?

J: I don't know. I've got so many things that I could do. And it's such a lot of detail, it's too hard. It's not really the right time in my life yet.

W: Do you know of any other companies or research groups in New Zealand that have an interest in microfabrication?

J: I know that there is Callaghan in Wellington, for instance, like the Callaghan group there is a small little microfab lab. A guy called Andrew Best, I think you've met him.

W: We've talked to him.

J: Ok, so he has good interest and he's helped us a little bit. So not really. I can't imagine that there wouldn't be. There's no cluster so there's no real conference or anything. As far as I know. Just so busy and trying to get our stuff going without worrying about other people's problems, you know.

Interviewee: Leo Browning

Interviewer: Rachel Ooyama-Searls

Organization: Victoria University of Wellington

Location: Wellington

Date and Time: 20/1/2016 11:00:00

Rachel: What is your name for our records?

Leo: My name is Leo Browning

R: And what is the name of your organization?

L: I'm working here at Victoria University of Wellington but I'm also funded through the MacDiarmid Institute which is throughout New Zealand.

R: Which part of the microfabrication industry are you personally involved in? Supplier, manufacturer, research, or student?

L: I guess Research and Student if that makes sense. I'm a doctoral student so I do research.

R: What part of the microfabrication industry is your organization involved in? Again the same four.

L: Definitely research at that point.

R: What is your job title? Microfabrication specifically carbon-nanotubes and nanowires. Take whatever bit

L: So I'm a PhD student as I've mentioned and I'm working in nanomaterials used in of that you want.

R: In your own words, what is your job description?

L: Ok, so that was the title, the simple idea behind it is Moore's law comes to an end eventually with the current kind of paradigm or architecture we have so we're looking at other materials that may allow us to go smaller or compute differently. The job title is that. Ok.

R: What does the word microfabrication mean to you?

L: Well, for me particularly it's a research and design process but in general anything to do with micron-level manufacturing usually for electronics or bio-sensors.

R: How does microfabrication play a role in your organization?

L: The MacDiarmid Institute is what I'm going to focus on because obviously the Victoria University is much broader. So the institute has sections on advanced electronic devices and novel materials which would then be used in microfabrication for electronics. So I guess those are very applicable. And then also some work on power generation which I don't know if it falls under microfab but solar and things like that.

R: In your opinion, how has miniaturization changed technology in New Zealand?

L: Has it changed?

R Or has it?

L: Ok so miniaturization has changed technology globally for obvious reasons. I mean, microchips and what have you are fantastic things. In New Zealand, I think it's at the beginning of changing away from a primary industry based country which what it is, and historically has been, moving towards what it needs to be as a small global economy which is a tertiary and knowledge based economy. So I see that beginning and I also see that continuing.

R: What do you imagine microfabrication in New Zealand to be like in 5-10 years?

L: Well, best case scenario you'd have more groups like the MacDiarmid Institute, like the Dodd Walls Foundation, like Callaghan coordinating between institutes in New Zealand and working together to produce what I was talking about. Kind of tertiary and knowledge based industries, microfab is one of those. So 10 years? Yea, I'd like to see that in 10 years, that would be great.

R: How do you see ongoing miniaturization affecting the future in 5-10 years? Or do you?

L: So I think miniaturization is going to be less of an issue. We're getting towards as small as we can get, realistically. At least, in the areas that we are working on. So I mentioned that a little earlier. So I think working at a lower scale is going to be still extremely valid but just purely making what we got smaller is perhaps not the best way of looking at things.

R: How do you think miniaturized technology has impacted society in New Zealand?

L: So this is once again probably just a global answer and New Zealand is a reflection of that. But I mean, miniaturization of technology has improved accessibility because often with miniaturization it's all about process optimization. So when you optimize a process you either get faster, cheaper, smaller, or better. Sometimes a combination of the two. It has made technology more accessible and it's made it more prevalent.

R: In your opinion what are the strengths of the microfabrication industry in New Zealand?

L: The strengths, okay, the collaborative atmosphere. I'm going to speak purely about the research side of things. There is manufacturing and this touches on the collaborative atmosphere as well. So in the research section, we often work closely with the manufacturing sector often for some equipment and expertise they have on processes and they work with us for research essentially, for investigative work and sometimes equipment that we have that they don't. Why I think the collaborative environment is so important is that there is a lot of big companies around the globe, big countries, big research economies, and there is no reason why a small country, small economy, small research group can't contribute but it needs to be in a collaborative way in order to best engage on a global scale, compete.

R: Next question. What are the weaknesses of the microfabrication industry here in New Zealand?

L: Scale. Size. Right. So the issue is size and mostly that comes down to equipment, right. Because the equipment is the money that is the bottleneck so funding is not as prevalent here as elsewhere. Now, I would say size and money would be the weakness.

R: How do you feel about collaboration with other organizations?

L: So I think it's fantastic. I think there needs to be more of it. Generally and especially in research and microfab falls under that easily, I think. It's really silly for three people toiling away trying to beat each other at the same research because then one of them publishes and the other two are effectively obsolete. Where as if they had all been working on the same thing or at least working together then they could have had, in my mind, even more than triple the progress because you learn from other people's mistakes. So I think it's absolutely vital.

R: What do you know about industry clusters and how do you see a cluster operating?

L: So a little bit vague. Industry clusters? I don't know. From a research perspective, a cluster is usually, well kind of an ad mini word for a group of researchers usually with ties to other institutes and industry partners. Once again, it's a little bit of a jargony term, I'm not sure how you are using it.

R: So an industry cluster would be like what you were saying with the research, the manufacturing, the supplier companies working together.

L: Right, so it's a vertical and lateral grouping of collective work.

R: Yes. How aware are you of the microfabrication facilities in New Zealand?

L: Pretty aware. Mostly because it's an open-end collaborative environment. There are a couple of places that I've only learned existed recently and I don't know anything about and it stays that way because, you know, they're working on proprietary stuff. But for the most part, it's pretty open, everybody communicates. If one person needs something or if one group needs something done or process there is usually a pretty helpful environment and the facilities are generally pretty good.

R: How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication field? Why or why not?

L: Ok, very interested. Mostly because it allows everybody involved to leverage the skills and facilities of kind of different levels if you will. So, like I mentioned earlier, as a researcher, we have a certain freedom in our work. We have a lot of tools and people and expertise designed to work on fast turnaround prototyping. Industry has a lot of expertise around manufacturing and high throughput. They often have a little bit more money in it than, you know, suppliers, even more so, more money, more throughput, you know, so it's kind of a spectrum. If we can all access all of those points, I think we'll all be more effective. So yes, I'm in.

R: Shifting gears here, are there any environmental concerns with microfabrication and if so how are they dealt with?

L: I would say no. I mean on the scale of research and manufacturing the environmental impact of microfab is relatively low. The only issue is some microfab processes, depending on the materials you are using, are heavy-metal based or based on, kind of, rare earths and other materials that have questionable, kind of primary source practices, right. So if you're getting niobium, you have to think about where niobium is coming if you wanna go environmental impact but I mean, we don't have smokestacks, we're not venting or dumping anything, you know. It's small scale manufacturing. Even a high throughput, you know, microfab company isn't producing that much physical volume.

R: Ok. What types of government regulations affect your work? If any.

L: My work, personally, is, obviously if there is anything to do with education funding but then that's kind of secondary. My funding comes through the MacDiarmid Institute which gets its funding via the MB, which is the Ministry of Business, Innovation, and something else. Anyways, they're the big funding buddy, that's definitely where all the money comes from and where they decide to put the money is always the limiting factor in the research side of things.

R: Are you doing any research in microfabrication? If so, what are the applications of your research?

L: Ok, yes. We've covered some of it but I'm definitely doing microfab research. My research is specifically, so I've told you the things I've worked with. So I'm looking at producing, well doing research, first of all just into the characteristics of carbon nanotubes and their use in electronic devices and then also the use of physically-based neural-nets. So instead of simulating a neural-net, we actually produce a neural-net with physical connections. The idea being twofold: one, it's an interesting computing paradigm which is already being leveraged hugely right now via simulated neural-networks. So Google's, kind of, deep-thought algorithm and things like that are all neural-net but they are very intensive so it takes a lot more transistors to simulate a neural-net than it does neural-net connections if you can do it physically. So that's one side of my research and then the other side is looking at carbon nanotubes and their use in transistors, mostly for sensor applications. So they're very sensitive to gasses and chemicals and things like that. So that's my field in microfab.

R: What degree are you pursuing?

L: So I'm doing a PhD in Physics right now.

R: Are you looking to get a job in New Zealand or somewhere else?

L: Ultimately, I'd like to be in New Zealand. Microfab would be nice, but you know.

R: So how come you want to stay in New Zealand?

L: I like the country, I like how relaxed things are here, I like the fact that it's not super crowded and I think in general that's the draw of New Zealand. So if you just want to make the most money you can nobody stays in New Zealand for any field except maybe dairy farming. But, none the less, a lot of people live here and a lot of people choose to move here from other places because it's a beautiful place. It's got a lot of natural beauty, it's not super crowded, it's very relaxed on kind of a world politics and governmental stage and I think all of those reasons are probably my reasons. Also, I've been here for 10 years and I've grown to like the place and it seems like a good place to settle down.

R: So we are coming to the end here, do you have any additional comments you would like to add?

L: So, you would be interested in putting together a cluster?

R: Yes.

L: So, are you seeing that there's a void in that regard in New Zealand and that's why you're looking at it? I guess what I'm asking are what are the closest things to the cluster that already exist or have you looked at those?

R: I think that there are some cluster objects sector by sector. Like for research, there is obviously some collaboration between everyone for industry there might be. But I think looking towards the between the levels there's. We've talked others and they've said there

has been gaps between industry and manufacturing or manufacturing and you know. Also looking to get to the global market is difficult as well.

L: So, in your kind of vertical stack, you've got research, industry, and supply? Is that they way you guys are kind of delineating it?

R: Education as well.

L: Education? Ok, kind of tertiary education though correct?

R: Yea.

L: Ok so does what I do fall under education? Like is post-graduate?

R: Yea, education and research kind of blends a little bit here.

L: Because as an undergrad, I can't remember ever touching on microfab.

R: Yea, it's more graduate students that

L: Right, and as a grad student, you are doing research as well. So they are a little bit mixed.

R: It's more for students because we want to know where they want to get a job as well. That's why we separate it.

L: Well I had another thing that I wanted to say. So, people in my field graduating, I think the statistic is like 99 or 98 percent, don't quote me on that, but it's a huge percentage move into industry and then a large percentage of that are moving into an industry that's not what they spent their degree on. I would like to see that be higher and part of that would be some kind of, more job opportunities in New Zealand and globally. Are there actually supply in New Zealand? Microfab supply or? I mean, I know there's industry.

R: We talked to one supplier. We're actually at the beginning of our interview process, we have a lot of people to talk to. It does seem from what we have done so far that there are some suppliers but they do not seem as common. A lot of stuff is imported and that can also be an issue, something that is holding the cluster back as well.

L: Lack of supply. Because one of the issues we have is often getting materials and it definitely is a block. Often you're sourcing things from Australia in the best case scenario and even then, they are almost always sourcing from Europe or the United States and so we have problems with certain chemicals where just the kind of hazardous shipping is twice the amount of the chemical.

Or we just ordered a set of special equipment and tweezers and they took 6 months to get here. That's a block. That's a big block.

R: I know one of the things that we are hoping for the cluster is that certain groups have certain connections to some places and if they are all sharing that information, then they can all have that connection.

L: Yea, and so there's some of that. A lot of it's just between research institutes but also with Callaghan, less with some of the pure industry and that would be great to have some of that con- especially because industry often orders 300 of something and it would be very easy of them to tack on another 2 for research but because there is no communication or not enough communication there, that doesn't happen. That would be really beneficial I think.

R: Do you wish to remain anonymous?

L: My name is fine.

Interviewee: Maan Alkaisi

Interviewer: Rachel Ooyama-Searls

Organization: Canterbury University

Location: Christchurch

Date and Time: 4/2/2016 11:00:00

Rachel: For our record could you please state your name and the name of your organization?

Maan: My name is Maan Alkaisi and I'm from Canterbury University in the department of Electrical and Computer Engineering.

R: Would you like to remain anonymous?

M: No, I don't mind.

R: Which part of the microfabrication industry would you say you're personally involved in? Supplier, manufacturer, research, or student?

M: Research.

R: Which part of the microfabrication industry would you say your organization is involved in? Again, the same four options.

M: It's research.

R: Can you please state your job title?

M: I am a full Professor in microelectronics.

R: In your own words, can you give us your job description?

M: Well, I'm principal investigator of MacDiarmid Institute for advanced materials and nanotechnology and this is one of the research of excellence in New Zealand. And my job is, of course, is to research, supervise PhD students, and train and supervise most doctoral follows. And as a professor of the department of electrical engineering, I teach undergraduates courses, I teach postgraduate courses, I supervise PhD students, I run a number of projects, contracts, etc.

R: Gotcha. What does the word microfabrication mean to you?

M: It's very cool word. It's the say that it's behind all the progress and development in the electronic industry which is one of the biggest industry now in the world. The microfabrication is the design, fabrication, and testing of devices and structures of the micro scale. And my specialization is beyond that in the nano scale so similar definition but when the device structure is in the nanometer scale.

R: How does microfabrication play a role in your organization?

M: Of course we train students on the design and fabrication of microstructures. We teach our students the applications of these microstructures in various industries and we also conduct research in these areas, in order of course to find new and innovative designs and devices at that scale. Is that answer your question?

R: Yea. They are very open-ended questions. How has miniaturization, in your opinion, changed technology in New Zealand?

M: It change technology all over the world. And New Zealand is part of this world. So miniaturization has enabled us to embed so many different functionalities into a very small device. So it makes the device faster, has a much larger memory capacity, it's a lightweight, the battery lasts longer, the functionalities of course tripled, ten times more than what used to be before. All this achieved because of the miniaturization.

R: What do you imagine microfabrication in New Zealand to be like in the next 5-10 years?

M: Well as you know, New Zealand is an agricultural country. The economy is based on the dairy industry and tourism. But we're trying and many others to establish high value technology here in New Zealand. For example, the MacDiarmid institute also part of the and very important part in establishing spin-off companies that uses kinda miniaturization, micro, nano scale devices and structures. So I expect that in the 5-10 years, that some of these spin-off companies will be mature enough to have an impact on the economy. Because, as you know, when you start with a company that makes five, ten million it doesn't make a dent in the like twenty billion or thirty billion dollar industry but I suppose the nanotechnology is still at every stage everywhere in the world but the potential of it is huge so expect that it won't virtually happen. There is one, by the way, company from the States want to set a semiconductor fabrication facilities here in New Zealand. They've contacted us and it's a lot of work to get this done. This is a guy from the States who is… He want introduce semiconductor industry to New Zealand. Be famous that he was the guy who did it. And of course he love New Zealand and the environment so he like to come and live here but at the same time, having for us was also what can that he will of course find jobs for our students. We can have a lot of collaboration, they might sponsor our research work and all that because we don't at the moment have really big layers in the semiconductor industry in New Zealand.

R: Can you say the name of that company?

M: As you notice, these things are not… until it's set I don't think I'm allowed to say but I can tell you that there is an intention so your world is not totally hypothetical and out of the blue.

R: How do you see the ongoing miniaturization of technology affecting the future in the next 5-10 years?

M: I think one of the major- I mean, in addition to the computer power that we can have, the power that our cell phone can have in addition to that, it will have a major impact on the health system. So because of aging problem, because of the population growth, because of the life expectancy all these cause a lot of challenge for governments to really keep the health system in good health. So, there's going to be lots of applications where devices will be imbedded in our body to monitor our health, to allow us to detect early stages various diseases because we usually we get … and then we understand that there's something wrong, it's too late usually. So the technology alone will enable us to be ahead of these diseases and also might consider a lot of targeted treatment where these devices, nanoparticles and such can go to where the problem is and try to solve it earlier and more accurate. Even the way that we take medication. At the moment, we take medication and it will go all our blood system to the parts that need them and to the parts that don't need them and this is why you always have side effects. So the targeting release of medication can be also some very important development. And of course, all the robotics that will provide help for elderly people and to the intelligent machines and especially in the car industry with self-driven cars, self-parking and you name it. The draw is going to be something where you know they might solve the traffic jam problems, delivery, the many many things that you can do with talking about drones that can chase, for example, a stolen car. So instead of a police car making a mess and you have all sort of accident, you send one of these and it will keep attacking this until it can detect an aversion like a dart with tranquilizer, you name it. But this is what probably what's coming.

R: How do you think miniaturized technology impacts specifically society in New Zealand? Or does it?

M: It's, well, let me say the cell phone and all the social media is a result of miniaturization because now you have your phone you anywhere you can contact all your family and friends and how we communicate now with each other, how we socialize, how we celebrate, how we share information and all that it's all been affected by this little device which is a result of miniaturization. Of course you are not of the age where you remember the phone it was that big. So it already has affected how we communicate with each other even inside the family. It's all electronic communication isn't it?

R: So what do you consider the strengths of the microfabrication industry in New Zealand to be?

M: Well because I kinda have to rephrase, we don't have a microfabrication industry as such. I mean there are firms uses ready-made devices that use it which use it the microscale structures but they are still at a smaller scale than what we want but it is growing which is encouraging. The main thing that the government realize is that this is where the future is. This is where investment has to be made and it definitely it's the, as anything else, is when you enter into it I feel like this one highly competitive. So you have to think that and compete with Korea, Japan, with Europe and this is why the government sometimes reluctant because they want to make sure that we get into a niche market where we can flourish and compete and so far, the dairy industry is, of course, you cannot compete with that with people that eat milk and meat and all that and we do very well. But, the dairy industry itself needs a lot of technology to keep up and this is where we also start thinking how we help them with the nanofabrication and microfabrication. There are of course many areas where you can improve the product through technology. And things like again, drones are already used to control you know, there's livestocks and all that and give them information.

R: Herd?

M: Yea, so there's already some technology and of course there are lots of technology in Fonterra, one of the largest dairy company in the world, it account for thirty percent of the dairy industry of the world although we kind of very small country but thirty percent of the dairy industry is from the. So, contamination, minute contamination in any part of these would cause huge disaster. So they have of course a lot of research to monitor, to detect, to prevent, to try all this new technology, to do this very fast, very accurate, etcetera. So even the dairy industry needs a lot of technology which eventually gonna happen that will benefit both sides. So the technologists will get their technology used and the dairy industry will sell their product more, can import and get more profits.

R: Ok, so the next question is what do you consider the weaknesses of the microfabrication industry or I guess lack thereof in New Zealand?

M: I personally always complain about the lack of investment in research in this area so we still don't have support, financial support from the industry to develop this ideas that we have so our main funding is still from the government, we don't have any fund from the industry so far. And, I think this is the major weakness is the lack of funding to support developing ideas in this area.

R: How do you feel about collaboration with other organizations?

M: Well this is extremely important in New Zealand. Why? Because we small country, because we have limited resources, so the only way that we can do better is by collaborating with each other in the state of competing because if we compete on the small amount of fund that available, we all lose. This is only way and this is what the MacDiarmid Institute is doing is really bringing people from different institutes like we have a Victoria University, Auckland University, they all part of the MacDiarmid Institute and this is how we… Once you know people, collaboration will get a lot stronger because we are not exactly the facilities that they have, the specialization, the problems that they are studying they are not answered and that of course build a much stronger collaboration programs. So it's very important anywhere in the world but it's especially important in New Zealand because of the limited resources.

R: How aware are you of the other microfabrication facilities in New Zealand?

M: I have very good idea of the fabrication facilities in New Zealand. As I said, this is through the MacDiarmid Institute, is through this it created an environment where we can interact. Here at Canterbury, and I can give you this just so that you know what we do here, we have this centralized facilities for micro and nanofabrication in New Zealand so the nanoscale devices, it's made here at Canterbury University but there are enough fabrication facilities in for example, Victoria University and in Auckland but these are for micro not for nano scale. Even the micro scale fabrication was started here at this, we are a little bit ahead of other institute as far as fabrication. But your question is how familiar I'm with the others, yes, I'm very familiar and they also familiar with what we have.

R: How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication field? And why or why not?

M: Definitely will be very happy to be part of an initiative that brings all those institutes together because this is the idea of cluster, I would say. Where you can do from because Universities do basic, fundamental research but at the same time, especially for engineers like me, I always look at applications, so I want to apply the technologies that I develop here and this is probably one of the limitations that we have here is the prototyping. Transferring the technology from research lab into industry has to go through prototyping and a cluster like you mentioned will provide that environment so that we can prototype the product or ideas that we have.

R: Sort of shifting gears here, are there any environmental concerns with microfabrication and if so what are they and how are they dealt with?

M: Especially with nanoscale particles, structures. We are not like fully aware of the long-term risk of exposure to these particles. Some of them we know, some of them we don't know. And usually scientists are very excited about their ideas and they might get too excited and not really think of the risk side of the work but as in anything you do in life, there's always a risk and you have to, I mean the first thing I always tell my students, use common sense. If you don't know something, be careful because then you don't know and until you know what it is, don't, and this is why we wear gloves, goggles, masks, you name it when we deal with structures that we know of but the question is there a risk? Definitely there is that risk with anything that we don't know. Until we know what it is, then we do test on it then until satisfied. But I expect that all scientists will have the common sense and ethical values that they will not do something that can harm or risk others.

R: What type of government regulations affect your work?

M: See, I work in a University where there are of course regulations, what we do and what we can't do. Our main work is research and teaching. My other position with the MacDiarmid Institute is mainly research and so there are some ethical obligations. Probably one of them is this risk factor that one will have to take. You just follow the command and regulations. The main really factor for our work is funding. That will kinda limit how much we can expand, or shrink, or focus, it's all given by how much money you have. So that if you wanna ask me what limits you, it's the first thing that will come to my mind is funds.

R: What is your current approach to stay relevant in the rapidly expanding field of microfabrication and nanofabrication?

M: Well that's a good question. And probably you will benefit from it as young engineers. You always think ahead. In the five or ten years or ahead. And see what are the major problems? And you think and align your work so that you always be on demand. So you be relevant. For example, many years ago, I realized that the biomedical field it's where there's gonna be a lot of interest because of environmental issues and health issues and aging and population and etc. So this sector will be very important, (...) the other area is energy. Again, very important area because all our activities is linked to how much energy we spend and energy is a huge problem. The more we consume energy, it will affect the environment, we harm the environment it harm our health and so forth. We reducing consumption of energy, we limit all the factions that we can do. So it's a challenge say it's something I also do a lot of work in that area. So always think about what is coming, what are the main issues in the world trying to align and you will be on demand and it's not just on demand, every day I come here I feel excited that there's something new that's something relevant that my work will help others. It's very important that your work is relevant to real problems in the world.

R: Is your organization looking to hire more staff?

M: Not currently, definitely not. Because of the earthquake that happened five years ago. There is a reduction in the number of student and that of course led to reduction in the number of staff and limited the new positions so currently we are not hiring new people.

R: What factors do you think make it difficult to compete in a global market?

M: The reason New Zealand choose a niche market is because of this competitiveness. We know that in technology it's a huge investment, the semiconductor industry if you wanna build a plant it will cost in the excess of 10 billion dollars so New Zealand is not in a position to make investments in such areas. You have to be wise which area you invest in and not compete with companies that are very well established, they already have the market, the name, the know-hows, all the intellectual property. So one have to choose areas where the big players are not playing and the niche markets it's more appropriate to New Zealand. Things that we could add but we'd probably have to focus more at because we know the market, we know how to compete in that area. I wouldn't for example, set a company to make a memory device because we will never compete with Taiwan.

R: What are the main and potential applications of your work?

M: As I said, there are two main applications but how did I come to these two? My main field is making micro and nano structures. So after developing the technologies for making these, engineering them with high precision, then I started looking for where to apply them. I apply them in two main areas, one to do with energy harvesting devices and the other in understanding how biological cells react to materials, to patterns, to topography and link that to some phenomenon that are not very well understood in our body.

R: How much money does your organization spend yearly on research and development?

M: Let me say that we generate around 70 million from research, from external research. This is how much money we bring to this organization. Sorry, this is only the college of engineering we're talking about not the whole university so we bring say 70 million. So this 70 million will make the most money that we use for research. The actual organization it's very hard to say how much on research. Because let's say they spend 2 million on buying new equipment but they also pay my salary and they pay for this office and they pay for the labs and they pay for the technicians, they all do research so it's really- I can't tell you exactly how much that can contribute to research. But the external number is something I know but the others are very mixed and difficult really to get a figure.

R: Do you know about the percentage that is spent specifically for microfabrication or nanofabrication research?

M: Percentage? Relative to…

R: The 70 million figure.

M: Probably between 5 to 10 million will go to the micro and nano, something around that including capital.

R: And how many people does your organization have on staff?

M: The University, well, we normally have about 17,000 students and around 2,000 staff.

R: How many people would you say does your organization have on staff specifically for micro or nanofabrication?

M: The total people using the micro and nanofabrication around 40 I'd say but those are include technicians, doctoral fellows, post graduates, so not staff but if you are talking about staff we probably only 6 that into microfabrication.

R: So now we're kinda coming to the end of our interview, I'm wondering if you have any additional comments you'd like to make.

M: Yea, I think I've covered most of the- I always tell my students that most of this development is because of material called silicon. So we are living the silicon age and this material is really the heart of the microelectronics and microfabrication. We kinda lucky that we have this material and it is abundant because we get it from sand, it's very cheap and will never run out but it's a very clever material, it sense light, it sense temperature, if you add impurity to it, it will change conductivity, if you apply electric field, it will respond so it's really a living solid state material and because of silicon we manage to make the transistors which are the most intelligent devices that we ever invented in systems of the digital and analog systems of the electronics and all the robotics and you name it. If you trace all this back, it's silicon and so we have always technology.

Interviewee: Mary Quinn

Interviewer: William Boyd

Organization: Callaghan Innovation

Location: Gracefield

Date and Time: 29/1/2016 15:00:00

William: What is your name?

Mary: Mary Quinn

W: What is the name of your organization?

M: Callaghan Innovation

W: Would you like to remain anonymous? We can ask this question at the end if you want to hear our questions first.

M: Come back to it at the end.

W: What part of the microfabrication industry do you align yourself most with? This can be a supplier, manufacturer, researcher, or student.

M: We're a government agency that helps companies be more effective at innovation particularly bringing new products to the point that they can be sold on the market. So, we as part of that, help companies with manufacturing methods. So we would assist them with having expertise ourselves around microfabrication and also expertise to link businesses in New Zealand to other sources of microfabrication experience or actual facilities.

W: What is your job title?

M: Chief Executive Officer.

W: Can you provide us with a brief job description?

M: I'm responsible for all aspects of the operations and achieving the mission and government intended outcomes of this government agency and responsible for using our budget to achieve our mission.

W: Thank you. What does the word microfabrication mean to you?

M: I'm not an expert at all on microfabrication but to me it means very small scale techniques for manufacturing goods and parts or components and managing materials that are very small scale.

W: How does microfabrication play a role in your organization?

M: It would be one of the manufacturing techniques that we would want to understand and know about so we can help businesses who are our customers use microfabrication when they need it to develop their own products.

W: In your opinion, how has miniaturization changed technology in New Zealand?

M: Well I think the same as its changed technology anywhere in the world not necessarily unique to New Zealand but it's just been an essential part of making all kinds of products possible at a size and effectiveness that wasn't possible before. So it could be anything from medical devices to wearable technology to technology that might be used say in New Zealand in the agriculture sector. Sensing devices, having things miniaturized enables them to be carried on say unmanned aerial vehicles as sensors for different kinds of uses. So many many different applications.

W: Thank you. What do you imagine microfabrication in New Zealand to be like in 5-10 years? Or how do you hope it to be like?

M: Probably pass on that because I just don't know enough about it specifically.

W: How do you see ongoing miniaturization affecting the future in New Zealand in 5-10 years?

M: I think that it's something that we need to stay on top of what is leading edge capability from anywhere in the world and be able to adapt that capability to the benefit of New Zealand companies and of course to the extent there are researchers doing their own breakthrough work in microfabrication and microfabrication techniques would obviously want to encourage the uptake of those skills by businesses.

W: Thank you. How do you think miniaturized technology impacts society in New Zealand?

M: It just makes products possible that didn't exist before or makes them smaller, or cheaper, or easier to use than existed before. Again, the same as probably any other industrialized country.

W: In your opinion, what are some of the strengths of the microfabrication industry in New Zealand?

M: I probably can't answer that in a useful way.

W: How do you feel about collaboration with other organizations?

M: It's essential to what we do we are part of the New Zealand government's business growth agenda to have a more diversified economy, to strengthen the manufacturing capability and manufacturing sectors and high-tech digital sectors. So that's only going to happen with collaboration across many parts of the economy, different universities, research labs, venture capital, community, the education sector, teaching the skills that the future workforce needs. So collaboration is at the heart of everything we do.

W: What do you know about industry clusters and how do you see a cluster operating?

M: We use the concept of clusters a lot in what we do so we identify constantly firms that are sharing a common problem or trying to pursue a similar opportunity where they are not directly competing with each other and help bring them together to as a cluster to solve that problem or explore that opportunity together in a way that's cheaper for them to do it to share the cost than if they each tried to solve the problem on their own.

W: Definitely. How aware are you of the different microfabrication facilities here in New Zealand?

M: I don't have a lot of detailed knowledge, no. But we have people in our organization that would have that knowledge.

W: How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication industry here in New Zealand?

M: I think our science and engineering experts and the design and manufacturing space would certainly want to be involved in and part of that kind of activity.

W: Are there any environmental concerns with microfabrication and if so, what are they and how are they dealt with?

M: Pass on that, I don't know enough about it. Oh except I have read that nanotechnology particles going into the environment is the problem. I'm not an expert on it but its one example of being aware of the general press of what some of the risks may be.

W: So, what types of government regulations affect your work?

M: Depends what you mean by government regulation because we are an agency of the government. Obviously all of the regulations that have to do with our government agencies operate directly affect us. But, we also help the businesses we work with, helping them grow faster and we often find ourselves helping make sure that they're aware of regulations that affect their industry and where they can get information about it. Whether it's regulations around health care, it's regulations around safety of food and beverage products. So we're kind of a contact point for them to get information about regulation.

W: We just have a few more questions. Do you have any additional comments that you would like to add?

M: No. Just be interested to see what you conclude from your report at the end of it.

W: Ok, and would you like to stay anonymous?

M: No.

Interviewee: Michael McILroy

Interviewer: William Boyd

Organization: Rakon Ltd

Location: Auckland

Date and Time: 27/1/2016 11:00:00

William: What is your name?

Michael: Michael McILroy.

W: What is the name of your company?

M: Rakon Limited.

W: I'm going to ask right now, but you can withhold until the end: Would you like to remain anonymous?

M: I'll withhold until the end to decide.

W: Which part of the microfabrication industry are you personally involved in? This can be supplier, manufacturer, research, or student.

M: Manufacturing and research.

W: If you had to choose one, which one would it be?

M: And this is me personally or for the company?

W: Personally.

M: Me personally. That's a challenging question. Probably the research.

W: What part of the microfabrication industry is your company involved in, given the same options?

M: Both research and manufacturing. But if you wanted one for the company, then it would be manufacturing because we are a manufacturing company.

W: What is your job title? Can you give us a job description?

M: So my job title is Product Research and Development Engineering Manager. I manage a team of engineers and scientists involved in doing technology research and product development for obviously our products and our manufacturing processes.

W: What does the word microfabrication mean to you?

M: It means methodologies, techniques, processes to assemble or construct devices that have very small feature sizes. There's always a range of what you define to be microfabrication, but probably generally, sort of, around once you start getting into a micron-type size, something like that tends to fall into that bucket.

W: How does microfabrication play a role in your company?

M: So, a range of things. So we have an ASIC design team which is based in the UK and so we design our own ASICs. And so we deal with subcontractors, fabs to build our silicon based ASICs, so we have that sort of subcontractor-type arrangement. Then, from a knowledge perspective, we then have to understand the construction, the designs, the processes, and investigations of those things. In terms of directly within our products, we sort of have two main technical fields within our products that we deal with. One is electronics and the other side is sort of quartz piezoelectric resonator. So on the electronics side we design/assemble our electronic designs or the ASIC portion of it. On the quartz resonator side, we design and manufacture and we have processes and so forth. So we've actually spent a number of years now developing some microfabrication here ourselves for manufacturing fine feature quartz resonators. So we've implemented etching and photolithography processes here with our own lab and are going into some production areas there. We've also done research with some local universities and technical institutes for some of those things as well. So it sort of spans a range of different things, so there's really those two core uses that we've got to. One as being a user of a fab for silicon assembly, basic manufacturer, then there's our own sort of development unique to our quartz resonators. Then there is the piece in the middle which is really sort of microelectronic assembly, which isn't necessarily on wafer based, but maybe different ways of assembling things and we're sort of touching on that area, but very difficult to do from New Zealand. So all of that we do through Asia mainly.

Tyler: So when you say ASICs, I'm not really sure what that means.

M: Okay, sorry. So ASIC stands for Application Specific Integrated Circuit, so effectively it's an integrated circuit which is designed for a special purpose. And so anything which people design for their own use and not for general sale is generally called an ASIC. Or it has a specific purpose, so we design an ASIC for our own products, multiple ASICs for our own products.

W: How has miniaturization changed technology in New Zealand?

M: It's a good question. So in general I'd say within New Zealand, not very much. So we're not particularly strong on the electronics side of things and so we're sort of late coming into that side. Probably the biggest area is maybe in some areas around biomedical, that sort of area. So there's been more work where - New Zealand is relatively strong around biomedical aspects and things like that and so there's been a number of companies and startups that use some of those things, microfluidics, that sort of stuff. In the area that we're in, the sort of electronics area, not so much. And apart from using things which are further out, but it's a difficult aspect for New Zealand to access different techniques or methodologies or things like that.

W: What do you imagine microfabrication in New Zealand to be like in 5-10 years?

M: So what I would hope for is really a couple of different aspects. One is the continuing of the universities and the technical institutes to implement some microfabrication labs and methodologies to develop that sort of foundation of science and engineering around that area. And that's slowly grown over the last five years, but has a long way to go. So I'd hope that that grows up and becomes a more common part of what we do. And then I don't see that - I think it would be very difficult for New Zealand to end up with a microfabrication manufacturing hub, but it would be very good. I think it would be very useful for New Zealand if we could have some sort of high technology prototyping-type capability where we have a number of companies who produce specialized products in consumer electronics or other applications but it's very difficult to experiment with things here in New Zealand. You can't go somewhere and say, "Oh, how would we construct these types of things?" So I think it would be very good if there was some type of microfabrication prototyping capability that could be accessed to help develop methodologies and approaches and then maybe farming that out to more of the manufacturing in Asia or something like that.

W: How do you see ongoing miniaturization affecting the future in 5-10 years?

M: I think that it will become a core part of all sort of technology as that becomes more accessible because you see a long period of time where feature packing, of different types of features into single devices and that sort of stuff, has grown a lot in the last ten years. And that will continue to grow, I expect. So that microfabrication, in terms of being able to cheaply assemble a lot of technology features into a small package and then use them in multiple places, I think will be very common and very core. So the only difficulty I think again reflects back to New Zealand is that generally the manufacturing implementation is very, very expensive. So it's quite hard to have a little bit of it, you know? You start talking many, many millions of dollars, tens of millions of dollars, hundred of millions of dollars, to really have facilities which are capable at the very highest level

W: How do you think that miniaturized technology impacts society in New Zealand?

M: In general again, because we're likely a first world country, we have all of the consumer overload of devices and all of those sorts of things, so you can see that spreading around just as it is in any other first world country. So it affects our communication, our interaction between people, the tools that we have to use. So it's really embedding technology into almost every aspect of people's lives.

W: In your opinion, what are some of the strengths of the microfabrication industry in New Zealand?

M: At this point I would say, if I'm considering it relative to other countries or centers, I don't think it is a strength at all. So we're relatively far behind in terms of how that is (...).

W: Also, in your opinion, what are some of the weaknesses of the microfabrication industry in New Zealand?

M: I think one of the core weaknesses is that we haven't ever had any of that historical microfabrication manufacturing center. We've never done IC semiconductor manufacturing or anything like that, so we haven't had that hub of foundation of resources and skills. So we're very short on skills and knowledge and I think it's very hard to replace that. I think that the key thing will be to find niche portions of the market where we can invest sometime which helps our particular industries.

W: How do you feel about collaboration with other companies and organizations?

M: Generally we would be fine to do that. We personally have found that difficult within New Zealand because there are no other companies that do what we do. So we're a one-off, and there are companies that do electronics and those sorts of things, but not really any other component manufacturers. So component manufacturers tend to get pushed down to the very small sizes, so we're sort of in a little bit in a limbo so we've struggled to find people that are really looking for the same things that we are.

W: What do you know about industry clusters?

M: I know sort of general approaches in terms of trying to put together a bit of a hotbed of associated industries and technologies that can sort of self-support and grow each other and share technology, IP, people, those sort of things to try and foster capability and growth in a particular area.

W: How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers? And why or why not?

M: I would say that we would probably be reasonably willing, but uncertain for the same reasons that I mentioned previously and that is: Is there really going to be a collection of appropriate alignment? To a certain extent, it's a little bit easier for us because we have absolutely no competitors within New Zealand, we have no competitors in Australia so it's not likely that if we were doing it within New Zealand that there would be anyone that would try and make competing products with us. So that makes it easier, but then on the flipside it's harder because are we really targeting the same sorts of things?

W: Are there any environmental concerns with microfabrication that you know of?

M: So in many cases, microfabrication uses a range of chemical based etching processes and those sorts of things. And so depending on how that's approached, it's an important factor in terms of the risks that may pose in terms of the types of chemicals that are used and so forth.

Overall, the volume of chemicals is relatively small, so that's maybe not so bad. But there are some very difficult chemicals to manage. So that's a risk that has to be taken into account.

W: What types of government regulations affect your work?

M: Within New Zealand?

W: Correct.

M: So, not many overall. We are effectively doing - 99.99% of our products are exported. So we're mainly affected by regulations that actually come from other areas like the US or Europe or Asia or those sorts of things. So most of the regulations which affect us here in New Zealand are about our operation. So Health and Safety, Resource Consents, those types of things. So having microfabrication and the chemicals and the processes and all those sorts of things, that's probably the main thing which affects us. And we're affected a lot by overseas requirements for products that we're going to sell.

W: How aware are you of the other microfabrication facilities here in New Zealand?

M: Not so great. I've had some contact with the Callaghan Institute and Auckland University have small fabrication here that we've contact with. Canterbury University and Victoria University. So, a little bit. In terms of other companies themselves, I haven't had any contact with any other company who's doing microfabrication on their own.

W: What is your current approach to stay relevant in this rapidly expanding field?

M: Yeah, so we're focused on doing some microfabrication in our unique quartz resonators because it's a relatively small industry and it's very difficult to find a partner or that sort of thing for that. So if we wanted to get into utilizing that methodology, we decided we needed to do it ourselves. So we'd approach that portion of it directly. We did some original work in conjunction with a government research institute, but then did most of the rest of it ourselves. In terms of the other microfabrication, related more to the electronics portion of it, most of that we're doing with manufacturing partners, contract manufacturing partners, those sorts of things on that side of it.

W: Is your organization looking to hire more staff?

M: Yes.

W: What factors make it difficult to compete in a global market?

M: It's a big long list. So, general cost competition is very difficult. So for us personally, that's probably our biggest challenge is trying to stay cost competitive, so you obviously need to make sure you have the right product that people want and then access to the right customers and the right market. We don't sell directly to the consumer, so we're a component manufacturer. So then it's being able to access the right companies and so forth and that's something that we've built up over 20, 25 years. We deal with many of the largest electronics companies in the world for our products, but if you're starting up, it is virtually impossible. You just don't get to knock on the door, to get in, to be seen.

W: What are the main and potential applications of your work?

M: So the main application's really in telecommunications, so all mobile phone networks, the Internet, data communications, those sorts of things. And also historically for us has been Global Positioning Systems, so we've supplied a lot of products for that application. And then going forward, the Internet of Things is another growing market, so anything that has digital electronics in it, you need some timing in that. And anything which has wireless communication and data communication also requires some sort of frequency reference.

W: How much money does your organization spend yearly on Research and Development?

M: That's a good question. Probably would be around about 30 million dollars, something like that.

W: And how much of that goes specifically towards microfabrication?

M: Probably, in terms of developing it, probably only a couple million, something like that.

W: How many people does your organization have on staff?

M: Total or engineering or…?

W: In total.

M: Total. So directly, we have around about 800. And then with our joint ventures, we're around about two and a half thousand.

W: And again, how many with microfabrication in particular?

M: Probably maybe, that includes the ASIC design team network, that work, so maybe 15, 20, something like that.

W: All right, so we just have a few wrap up questions and then we'll be on our way. Do you have any additional comments that you'd like to add?

M: Nope, don't think so.

W: Do you know of any other companies or research groups in New Zealand that might have interest in microfabrication?

M: Companies, not really. But in terms of research groups, the ones that I've talked about. So Callaghan Institute, Auckland University, Victoria University, and Canterbury University are all particularly interested in that. Then we're also dealing with the Robinson Institute which is part of Victoria University, and we're doing some work with them. So those are the core ones that I know of that have particular interest in it. In terms of the biomedical side, I know that there's things that are going on but I'm not really in touch with it or know who they are.

W: Do you know anyone who would be willing to contact us at Canterbury?

M: Not off the top of my head, but I'm sure that I can find contact details for you.

W: And would you like to stay anonymous?

M: No.

Interviewee: Mike Arnold

Interviewer: Rachel Ooyama-Searls

Organization: Callaghan Innovation

Location: Gracefield

Date and Time: 14/1/2016 15:30:00

Rachel: Which part of the industry are you personally involved in?

Mike: Research, education, and sometimes, supplier

R: What part of the industry is your organization involved in?

M: The organization of Callaghan Innovation is involved in networking between various parties in any given industry if you are a reagent use drug use if you are looking at a micro sized diagnostic kit, you need less reagents there then you do in the, let's say, clinical setting

R: What is your Job title?

M: Well, I have two job titles. I am principal scientist and I team manager.

R: What, in your own words, is your job description, for both job titles?

M: I was a, my job description is, a, leading the research effort, looking for research opportunities, monitoring team performance, inspiring team for higher aims. And that goes down to the detail of writing reports, writing papers, writing grant proposals sometimes.

R: I realized I forgot to ask something pivotal at the beginning, could we have your full name?

M: William Michael Arnold

R: How does microfabrication play a role in your organization?

M: Microfabrication is used within the organization for helping people formulate and carry out leading edge research projects, and also it is used in order to help industry partners develop new technologies and sometimes also to enable new measurements for example to be made using very small components.

R: What are the main and potential applications of your work?

M: It is very difficult to judge the long term applications of something like microfabrication. My own work involves not only microfabrication but also materials properties measurements of various sorts. Chemistry and electrical. Microfabrication has the biggest applications I think in developing new biosensors, and other materials type sensors. Having said that, it is also used in metrology and possibly increasingly in photonics. Again, sensing comes into that.

R: How has miniaturization changed technology in New Zealand?

M: Not greatly so far. We are hoping to change that. But obviously, miniaturization helps to reduce cost, reduce drug use, reduce time to get a result. Depending on the area you are in, it can also give you increased accuracy in certain areas.

R: What do you mean by drug use?

M: Well, for example, and in a {…} lab.

R: What do you imagine microfabrication to be in 5-10 years?

M: I think there will be more of it. I think there will, still is a possibility of larger collaborations between Callaghan and the universities leading to a centralized facility somewhere. We have some indications that certain American interests are interested in manufacturing in this country, also, for reasons of their own, which you would have to ask them about.

R: How do you see the ongoing miniaturization affecting the future in the next 5-10 years?

M: Very greatly, and it already is, looking at cell phones and everything else of course. But, many things will be incorporated into hand-held devices which are not available yet so that people will be given better information about their health and many sources of data will be available to people even beyond what are available now. So, that not only will the device be able to measure what your biological signals are, it may will be able to diagnose it for your, which your primary health person may not like, but it will be possible.

R: How do you think the microfabrication industry impacts society in New Zealand?

M: As yet, not greatly, except for what things they can buy from overseas. We hope that obviously there will be more manufacturing here. At the moment it is just research and development really, and therefore the ordinary consumer doesn't see any of our products. Having said which, we know our company's already involved in possible ways of mass production of microfabricated devices.

R: What do you think the strengths of the microfabrication industry are?

M: Within New Zealand, I think the strengths are the ability to attract talented pools of people to take on new projects and at the moment there is no great industry funding there, except in one case where they are entirely doing stuff in-house. In terms of what people do with those talents remains to be seen in the next, say, five years is a good time scale, what is going to come after that.

R: What do you think the weaknesses of the microfabrication industry are?

M: Specifically in New Zealand, we have very poor facilities relative to what is available in other countries just because we are smaller and don't have the research dollars. In addition, New

Zealand suffers chronically from lack of industry investment in research and development compared to other OECD countries and that shows up in microfabrication area as in many other areas such that things could be going at a greater pace for at least ten years I think.

R: You think that is a major issue for being competitive with other countries?

M: Oh certainly, yeah, of course. It is one thing we try to tell the politicians all of the time and the politicians say the industry will be encouraged to spend more but somehow it doesn't seem to happen very fast.

R: What is your current approach to stay relevant in this rapidly expanding field?

M: Within Callaghan Innovation, we would like to help industries become more competitive in themselves. So, we inform ourselves in what is available and pass that information on particularly where we see a chance for new equipment to become available within New Zealand. We like to try to encourage a consorting of users perhaps to acquire that equipment because no single user can afford it. In certain cases, we may be able to buy that equipment ourselves and make it available to people, and that is the model in fact the microfabrication unit downstairs is trying to offer it. Having said which, we never get enough time to read all of the new publications and we never have enough money, of course, to buy all of the new equipment.

R: What do you know about industry clusters?

M: We, what I know about industry clusters is there is no big one in microfabrication in New Zealand and (…) could be on. I imagine that to be a very useful thing to have. But we have, let me see, there are industry clusters, in a loose sense in industrial parks in Auckland, but it is a fairly new concept in New Zealand I think.

R: How aware are you of the microfabrication facilities in New Zealand?

M: Oh, I think I know them all pretty well. So far, as they are public at all. There may be some that nobody knows about apart from the owners. I think you may find that you cannot get access to some of them yourselves.

R: How willing would you be to join a cluster initiative for microfabrication?

M: Oh, absolutely essential. If there is one, we should do that, yes.

R: Very willing

M: It is a part of our job

R: That is true. How do you think your organization would benefit from joining a cluster?

M: Well, in the sense that we are already trying to make one up, it would benefit our purpose, it would, if you like, benefit our end of the year report, it would be a KPI for us. (KPI = key performance indicator, Google)

R: What types of government regulations affect your work?

M: All sorts. Of course, safety is a major issue for us, so we take that for what its worth in terms of making sure that people do work safely and that sometimes can inhibit people working alone for example, which is typical in academia but not usual here. On the other hand, we do find that government can go over the top sometimes in prohibiting import of certain chemicals. So, that has been an issue for us recently with certain solvents, which are seen a possible drug precursors for example, and in those cases we are tighter in this country than some other countries, specifically the USA it is easier, not quite in the realm of regulations, but the fact that things have to be stamped and certified sometimes means that people are unwilling to import them at all, and if you want them to import you may have to go your own way on that, which is very expensive. So, all of these things can cause delays or extra expenses.

R: Do you have any additional comments?

M: Well, I suppose my concern is that you are coming from a country where things are different. My experience with the United States is that people have a very gung-ho attitude to just going ahead and doing stuff and in this country, although we encourage that, it doesn't always happen. People may think that it just is not possible in New Zealand because we are too small and it is New Zealand. We are a low-tech country they think. So that is an attitude you see here, and so, be prepared that some people may think something is not possible, even when it can be possible when you go and meet these people. So, that is (…) think wide about, if you do get the chance. Have an active role instead of being just reporters

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Interviewee: Paul Garrett

Interviewer: Rachel Ooyama-Searls

Organization: Photo Etch Industries Ltd

Location: Christchurch

Date and Time: 4/2/2016 13:00:00

Rachel: For our records, can you please state your name?

Paul: Hi, I'm Paul Garrett, I'm the Managing Director of Photo Etch Industries Limited.

R: Would you like to remain anonymous?

P: No.

R: Awesome. Which part of the microfabrication industry would you say you are personally involved in? Supplier, manufacturer, researcher, or student?

P: I'd be a manufacturer but from my understanding of microfabrication may not be yours. Before you came here I referred you to a website. Did you look at the website?

R: I think we did.

P: Alright, ok.

R: So our next question here, your organization would also be falling into the manufacturer.

P: Yea. We manufacture parts yes.

R: In your own words, can you give us your job description?

P: Well this is a small business started by my wife and I so I do everything that others can't do. I set the directions that the company wants to go, I am the source of technical innovation in the company, I meet with customers, set and maintain production.

R: What does the word microfabrication mean to you?

P: Microfabrication is making physical and electronic devices based on silicon wafers, the dimensions typically well into microns, stuff you can't see. That's microfabrication. I work in an area perhaps 100-1000 times larger than that. So there could be a cross purpose here. I know of microfabrication, I know what can be done, and I know how it's done but it's not done here.

R: My next question is how does microfabrication play a role in your organization?

P: We don't do any.

R: Right, ok. In your opinion, how has miniaturization changed technology in New Zealand?

P: You can't really answer a question like that. It's too hard and too big. How has miniaturization changed technology. It's a fundamental change. What used to be this big is now that big. What used to be that big, everything disappears. The change is profound and also obvious. It's almost an unanswerable question. Don't you think?

R: Our interviews are designed to be very open ended so people could take the question and do with it what they want.

P: I don't do much design work for customers. That's not the way industry seems to work here. I make parts to customer's specs and drawings. I make a big input into how it's made back to the customer and it changes from time to time. You know like "your idea is no good at all" but that's as far as I go.

R: How do you think miniaturization technology has impacted society in New Zealand?

P: Another unanswerable question. You would require 20,000 words to answer that. It's like this guy here on his keyboard, how has that keyboard influenced his life? He can't answer that in ten minutes.

R: Right. Would you say it's similar to the rest of the world?

P: Oh yea, yea. New Zealand's government and commercial infrastructure is very good. It's comparatively simple to take technological advances and apply them. Unlike other countries where the government can be quite restrictive, here it's not so.

R: What do you consider the strengths of high-tech industries in New Zealand?

P: Market. The market and the inability of the people involved to accept that it can be done here. One of the attitudes pervading the technological industries in this country is that it can't be done here. It has to be done overseas, over there, you have to import it. Many of these parts here, if the customer knew how they were made, they wouldn't have got me to make them because they didn't think that it could be made. You follow that?

R: Yea. They would have gone and outsourced.

P: Yea, they would have automatically sourced it elsewhere. They wouldn't have thought that someone could do it here in New Zealand.

R: So would you say that's more of a weakness then?

P: Is that a weakness? Yea, yea. But it's an attitude change that has to be made in society.

R: How do you see ongoing miniaturization affecting the future in 5-10 years?

P: Another 20,000 word question.

R: How do you feel about collaboration with other organizations?

P: Good. When do we start? You know, let's go. But commercial and technical attitude in New Zealand don't seem to want to go down that road. A lot of people are very secretive about what they do. And consequently that can put big barriers between supplier and customer.

R: Do you think maybe there should be more of a focus for New Zealand to think of themselves as one large group instead of individual people competing in New Zealand?

P: Collaboration and cooperation between companies is quite rare.

R: What do you know about industry clusters and how do you see a cluster operating?

P: What do I know about-

R: Industry clusters.

P: I know of them, I've heard people talk about them in New Zealand. It would nice to see it happen but it's not particularly likely because of the intersecting views that people take. It would be great to see it happen.

R: How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers?

P: Very willing.

R: Ok, and why?

P: Because it advances technology and the further into technology you get, the more exclusive it becomes and so the economics and cash flow of the organization becomes more secure and therefore it puts a predictable level of profitability on the company and it tends to eliminate competition. You see, that, I don't know anybody, I've spent time on the web, I don't know anybody who can make that under one roof.

R: Because they don't have the equipment?

P: Yea, the equipment and the expertise and stuff. Because that particular customer, their engineers are quite happy to say "Here's a drawing of what we would like, can you make it?" And I say, yea I can do it. And there is very substantial business to be had.

R: What type of government regulations, if any, affect your work?

P: The thing that sticks out the most is all the jeers and rears my tears with air freight. People think I'm sending B.O.M.B.S. and I've air freight shipments going to Sydney and the freight companies ask for the packaged stuff to be unpacked and inspected before they let it ship. This is kind of paranoia which comes from the United States Department of Defense.

R: You're not wrong.

P: Well you've been through enough airports to know.

R: One of my favorite things about New Zealand is the airports I can bring a bottle of water through domestic flights. That's wonderful. Ok. For our record, can you state what are the main applications of your work?

P: In the electronics and science industries.

R: What's your current approach to stay relevant in your field of work?

P: I don't know. I think that might be a 10,000 word answer.

R: How many people does your organization have on staff?

P: 5.

R: Is your company looking to expand and hire more staff?

P: I would like to because there is security in increased size and there's security in having a wider customer base than a narrow customer base and there's no substitute for the old dollar.

R: What factors do you think make it difficult to compete in a global market?

P: Credibility. I have a small website and my main export market is targeted to be Australia and there it's called a social objection that people don't wanna buy from overseas, they'd rather have it made locally. So if I say 10 dollars per part and the local man says 15 dollars per part they'll go with him. And you would expect that. I'd be doing that myself. But the type of stuff that comes out of the mouth of the Minister for Overseas Trade is largely stuff written by PR people.

R: How do you think international trends shape the future of microfabrication or miniaturization technology in New Zealand?

P: China. China. China. China. I get emails from a couple of companies in California whose job it is to deal with second-hand electronic fabrication equipment and in particular, the industry you were talking about. And as I speak, there's about one microfabrication company every fortnight is getting rolled up and sold off. Now … is a growing concern. They're breaking it down trying to sell individual pieces of equipment. And there are companies which may have perhaps to buy new 10 million dollars' worth of machinery and they're shuttling it off in little bits. The reason is not the quality or delivery, it's the price that China, or elsewhere, is charging. They're charging 5 cents for something that's worth about a dollar here. It's the government policy coming in from China and other countries. This TPPA treaty which I'm sure you may have picked up in the media.

R: Yes, I saw a protest.

P: Such treaties favor the interest of capital and not the interest of innovation or small business. There's nothing I can do about it. It will favor the United States. Yay.

R: Do you think government funding is an issue for high-tech fields in New Zealand?

P: Yea, at the moment, I would be unwilling to spend money on capital machinery because I don't see a market. I can't spend 100 thousand dollars on machinery unless I can see what it can do. I can't spend 100 thousand dollars on paying one staff member because I need to see that there is a future for what's being done. And I don't see that future. I hope I'm wrong.

R: So we're coming to the end of the interview here and I'm wondering if there's any additional comments you'd like to add.

P: Who else are you seeing in New Zealand?

R: We've seen the Photon Factory, can you show him?

T: This is our interview list.

P: I don't know anybody who's doing microfabrication. That's why I asked. There are a lot of people who are interested.

R: There are a lot of small startup companies that we've found. [redacted]

P: [redacted]

Interviewee: Paul Mather

Interviewer: William Boyd

Organization: Callaghan Innovation

Location: Gracefield

Date and Time: 18/1/2016 13:00:00

William: Would you like to remain anonymous?

Paul: No, I never stay anonymous.

W: For our records, can you please say your name?

P: Paul Mather.

W: And also, what organization do you work for?

P: I'm from Callaghan Innovation and I'm part of the manufacturing and design group and I look after the three workshops that we have in New Zealand. One in Auckland, one here, and one in Christchurch.

W: Thank you very much. Which part of the microfabrication industry are you personally involved in? This could be supplier, manufacturing, research, or student?

P: Probably none of those. I'm aware of them obviously particularly since I've started to work at Callaghan Innovation and we are, as a workshop, looking at the new directions where manufacturing is going, where technology is going and where we need to start to place our, you know, some of the new equipment we might be looking to purchase and one of the areas that we saw is certainly micromachining. Obviously interested in the crossover between microfabrication and some of the work that we're doing. My understanding is very basic in terms of the actual details of microfabrication, I'm certainly no expert on it.

W: Would you say more towards the manufacturing side if you had to pick one of the four?

P: Manufacturing definitely. That's where my experience has been.

W: What part of the microfabrication industry is your organization involved in primarily?

P: Well, obviously the group that you're working with is the area that's heavily involved with it although we're the sensing and automation group, particularly Paul Harris, is involved with doing very small sensors, transducers and stuff. So he's using some of the techniques that you use in microfabrication.

W: What is your job title?

P: My current job title is Engineering Technology Transfer Manager. So I'm acting in that role at the moment. That's quite a mouthful, I tried to shorten it but.

W: In your own words, could you provide us with a job description?

P: I'm responsible for the workshops within the manufacturing and design group. I suppose my role is to get the strategic position of those groups and to help to get them set up to do more product development with outside companies than they have been involved with before. Up till now, they've basically been a service group to the science and research teams particularly here at Gracefield. But now we're having to move to a different model and while we are still working for the teams here, there's a greater emphasis on working with external companies and helping their product development. So that's really my role. To help the groups set up the workshops, set up and get the sort of infrastructure and resources they need to take on that new role,

W: Thank you. What does the word microfabrication mean to you?

P: Well, since I've been working for Gracefield I thought that some of the work we're doing in the workshop, you know, was actually, like we referred to it as micromachining. And I thought, we'll just see about having been put right by the people in microfabrication. We basically we're absolutely miles away from what they, the level of, the scale that they're working at which is quite different from what we've been working with. So I've sort of had to get started to get my head around trying to understand what it is when they're working at that sort of scale of thin filament building up stuff on that scale and how it could be used. And I suppose the interesting piece of work that they've just been doing is looking at building electrodes through microfabrication and then we're looking to see if we can use those electrodes to spark eroding some very small components that we're working with at the moment. Because it would be very challenging to make the electrodes on our machinery because we sort of work in half a millimeter and that's it. No micron.

W: How does microfabrication play a role in your organization?

P: Well obviously it's been part of the science groups here and a lot of research. In terms of where we've been positioned, it hasn't played a large role yet and I suppose we're just exploring how we can work together and what opportunities there are to bring together the two areas. I think there's probably a lack of understanding, wide understanding of what microfabrication is all about in the general community. And manufacturing it will only be quite specialized small firms that actually have any idea of what it involves or what the potential of it is.

W: How has miniaturization changed technology in New Zealand?

P: I think it's growing, the impact. I'd have to say at the moment because we haven't had a semiconductor or chip manufacturing industry in New Zealand, the implications have been relatively small. With the likelihood of a developer or a company moving on shore to actually make semiconductors and diodes and stuff like that, it start to come into its own. There's a lot more, a big potential of an interaction between those two groups in particular. One of the things- you might have a question there about it but the scale of things in New Zealand is quite different from what you're probably used to in the United States.

W: Smaller population.

P: It's very small. It's probably a suburb of New York. With a million people, a million plus in Auckland. So the rest is sort of spread out over the whole of the country. So when we talk about small industry, we're talking about one to five people or one to ten people as our small company. If you talk about a company with a hundred people, you're starting to talk quite a big company. So just the scale is quite different.

W: That's very helpful to know.

P: What you do find is, you find niche companies working in specific areas where they've made a- they're doing something that's quite specialized that they can send overseas or can compete in the international market. We're very much a country that's sort of going through a big transition at the moment. Where up to now the dairy, the agriculture product has been basically what we trade on and the biggest company in the country is Fonterra which is a dairy cooperative and they basically sell bulk dry powdered milk and they are about probably 60% of our exports. So high-end manufacturing is where the emphasis is going now through particularly the role that Callaghan has got to try and up the level of product development that's taking place within the private companies in New Zealand.

W: What do you imagine microfabrication in New Zealand to be like in 5-10 years?

P: If some key industries do get established in New Zealand, I would believe that there is going to be a significant increase in the use of microfabrication. If you can get a small group of industry that is working together then you can grow a very close network of people who are supporting each other in terms of what they're doing, I could see it growing quite significantly if we get one big firm to be the sort of center around which some of the other elements can congregate.

W: Thank you. How do you see ongoing miniaturization affecting the future of New Zealand in 5-10 years?

P: I think it's going to be hugely important. One of the problems you've got from New Zealand is you don't want to be shipping here. So you want small, high value items that you can ship, preferably air freight. They've got significant value when they leave the country. So for New Zealand, the less you have to, the smaller you can make it, the better.

W: How do you think the microfabrication industry impacts society in New Zealand?

P: I would mention that most people wouldn't know what you were talking about. It would be within the universities and certain science areas but for other people, other groups, they probably haven't very if they've heard of it at all. It would be surprising.

W: Alright.

P: I mean, even the talk about semiconductors and transducers and diodes and how they're made because we haven't had an industry. It's not something that really figures in a lot of the training but in universities and stuff so.

W: Ok. In your opinion, what are some of the strengths of the microfabrication industry in New Zealand?

P: Callaghan Innovation. And I think the fact that we do have some specialists spread across the country who are well placed to be able to work together and to bring the very small number of companies that may be working outside in this area together. So you can very quickly form clusters here and it's quite good if they start smaller and then you can just add people to them or maybe identify companies that could move into this area from their current technology base and help them pick up their new piece of work or this new technology. That particularly, that is something that Paul Harris has done with a couple of companies in terms of screen and primping and stuff like that.

W: What are some of the, in your opinion, the weakness of the microfabrication industry in New Zealand?

P: It's basically it's the fact that it's not well known and the fact that it's that there probably is a very small base to start from. I know there's people like Rakon in Auckland and stuff that make, you know, a sort of cross into this field. But whether they fully actually be a microfabri-- I would stand corrected if they were doing something that was more… wasn't quite using all the techniques of microfabrication. But whatever it will be very small in terms of our scale and people understand agriculture and they understand how milk powder and horticulture and stuff like that but if you actually start talking to them about industry or manufacturing and the hard manufacturing industry, there's a lot less knowledge.

Rachel: A quick question going back a little bit. Maybe less of the microfabrication industry impact but more like how does technology like miniaturized technology impact society in New Zealand. Are they open to-?

P: Yea. I mean, there are companies working with in the area of making computerized control systems and radio systems and tight electronics around it and sensors is probably one of our is probably the bigger manufacturers in Christchurch and they're into mobile radio and radio systems and stuff like that. So they use transducers and stuff like that. Dynamic controls, we're making electronic control boxes for wheelchairs. I believe that a lot of the manufacturing has gone to China but they were doing a significant amount here. So there's a lot of companies using electronics but not a lot of supp-- they are basically buying components in from offshore. Rather than making it here.

W: Alright. What do you know about industry clusters?

P: A little bit. I've been familiar with them a number of years and I've been involved in getting some up and running.

W: Can you give us any examples?

P: We created one in the Hutt Valley around creative manufacturing which was about companies that were designing, reducing, and exporting product. So they were basically dealing with a whole chain of manufacturing rather than just making it and selling it to a home market or something like that. And there was a lot of learning that they could all do by working together and also just like "Ok, I'm shipping so much up to the States, I've got half a container is there anybody else who wants to take the other half" and things like that. So in a country that's small, they can be effective although New Zealand has always had the problem that they see their competition as the next guy down the road rather than the rest of the world. So getting them actually to work together can be a challenge because they don't want to reveal their secrets. But in many ways, the only way that they are going to be able to take, compete for orders offshore is actually to combine their resources because they are just so small. I worked for a furniture company that made, I think we assembled on a good week 200 chairs a week. We formed a relationship with Nolan in the States and they did 5,000. In the end, we just got, they became an assembly line because there was no point trying to make all the bits here where you were a day, day and a half of Nolan's production line for the year. You just shipped it in. Gives you a bit of an idea of scale. But there have been some successful clusters particularly in mainly the agricultural areas where they've worked together well. Clusters were the thing that everybody should do a few years back and they sort of fell out of fashion and now there's a few started up again. Callaghan has I think about four or five now where they are clustering people together. It sort of goes in a bit of a spin cycle.

W: Thank you. How aware are you of the different microfabrication facilities located in New Zealand?

P: I'm not. That's not an area of my expertise. So I'd like to learn as much from this report as you guys would. Paul Harris is one person who would be worth talking to. And obviously people like Andrea and the team that she is part of, they'll know probably the sector as well as anybody.

W: How willing would you be to join a cluster initiative for microfabrication and why or why not?

P: We would be interested in supporting it. Particularly because I'm interested in it in terms of the opportunities that may present with the fact that we're seeing a lot of miniaturization in some of the products that we are being asked to work on. Now that's miniaturization by machine shop standard not necessarily by microfabrication but I'm sure there's crossover areas. If we get Intrepid Group up and running here which they'll be producing components that we'd be wanting to use so it would give us our first onshore supplier of componentry and wafers hopefully…

W: Thank you. Are there any environmental concerns with microfabrication that you know of and if so, could you go into specifics?

P: No. I really don't have the knowledge of that except that I do know that there are some chemical solutions that are used that have some nasty some environmental challenges and certainly those some of the difficulties one would have in terms of getting sign-off permission from councils and stuff in terms of how you were to recycle, cope, dispose of those chemicals.

W: Alright. And I know I'm going to get a similar response but do you know of any government regulations that affect your work?

P: Well in terms of just generally I mean there's the Environmental Protection Act, there's Health and Safety Act, and you know the general ones we have to work under. So they would apply to microfabrication just as much as to ourselves with the bigger production that we're doing. Under this government there's certainly not been the focus on sustainability and the environment that there is likely to be if there was a change of government. They've put it aside but I think actually in many ways industries or businesses driving the sustainability message a lot more forcefully than the government itself. But even the government is running into problems with the 100% pure marketing campaign for New Zealand and people now saying, well can you actually show that you're 100% pure and asking the question. So sustainability is going to come back on the radar a lot stronger than it has and recycling and sustainability will be very important. There's very important locations for that in manufacturing in particular.

W: Thank you. What are some of the main applications of your work?

P: Of our work? The development of, the design and build of products or new products or processes for industry. A lot of it is fairly specialized equipment for manufacturers of other products so they need a new machine. They're working in, say, in their agricultural processing side and they need a new machine so they come to us to help them develop it and also to then get it into manufacturing in New Zealand. Which is a bit of a challenge behind it but one of the elements in that is that becoming more important are the computer control and the programming and stuff like that. All of those electromechanical systems that operate these machines at high levels of sophistication because that's the only other way we're going to compete with the Chinese manufacturing because they we have a free trade agreement so if you are going to be a New Zealand manufacturer in New Zealand then you've got to be capital intensive.

W: Alright, thank you. What is your current approach to stay relevant in this rapidly expanding field?

P: Well to explore opportunities and to try to stay at the leading edge of technology. So we're always scanning and locking it. What technologies can New Zealand adopt or are appropriate for New Zealand and how could we help industry to experiment with those technologies. For instance, with looking at a 3D sand casting, sand printing for the casting industry which is a way of producing molds for foundries which allows you to make an individual mold and then make a tweak in the next one and stuff that's, you know, build up 3-dimensional layers and so you just pour your metal into the cast and it basically burns off, you crack it off and that speeds up the speed in which you can produce metal castings. Now, it's being used overseas but for a New Zealand company to get into that particular business it's very expensive given their size. One thing we can do is buy a or create a bureau with a piece of equipment that all the different industries can use and I think there's definitely a role there for the microfabrication facility here is to become a core facility that other people can use to experiment and get to understand how to produce stuff and then see, you know, as demand grows or their expertise grows, they can maybe take the investment decision to buy their own gear. That's certainly one way we can see ourselves helping New Zealand industry.

W: Thank you. How do international trends shape the future of New Zealand microfabrication?

P: I think we're totally reliant on those. We have to keep looking at the trends and seeing which benefit we wanna specialize in. We're not going to do the whole spectrum. You can't be, we just don't have the scale or the resources. So, it's about going "Ok, we could do that bit really, really well" and to keep looking for those pieces as they're developing.

W: Is your company looking to hire more staff? Or are you maintaining it like a status quo?

P: In terms of Callaghan? Hopefully the workshop will begin having more staff. Just simply because the nature of the projects that we will be doing. We certainly hope so. So, we're a government entity so it's a little bit different from a commercial private company. We've got, as you probably know, this mandate to work to support New Zealand industry. It's a little bit different than being a private company where you make your own decisions.

W: What factors make it difficult to compete in a global market?

P: I think scale is a problem in terms of the expense of the machinery if you're getting into it. And secondly, it's the depth of knowledge that's available to you onshore. One of the interesting things we've found with work with Intrepid with their semiconductor and production and stuff like that is all the people that we've found at the universities are all from overseas because they're the ones that have had experience in the industry previously. Because we haven't had our own industry in this area, there is a problem between supply and demand. So often you're aligned with overseas people for a while to bring in the expertise to start with and then slowly build your own internal expertise. That's quite critical in terms of how you build your level of expertise.

W: We're pretty much done, I just have a few wrap-up questions. Do you have any additional comments that you would like to add? You can say no.

P: Probably no.

W: Do you know of any other companies or research groups in New Zealand that have interest in microfabrication and if you do, do you have any contacts and your connection with them?

P: Not personally, no. Andrea and the others will probably be able to give you the best range of contacts.

W: We've been talking to Andrea a lot too so.

P: And they understand the industry. I mean, I do have contacts with the American company that's setting up here in the semiconductors side. If need be, I can point you to somebody to talk to about that.

Interviewee: Richard Templar

Interviewer: Rachel Ooyama-Searls

Organization: Callaghan Innovation

Location: Gracefield

Date and Time: 18/1/2016 9:30:00

Rachel: Which part of the microfabrication industry are you personally involved in? Supplier, manufacturing, research or student.

Richard Templar: Research

R: What part of the microfabrication industry is your organization involved in? Again the same four options.

RT: Research and manufacturing

R: What is your job title?

RT: I'm the general manager of research and technical services at Callaghan Innovation.

R: In your own words what's your job description?

RT: I look after approximately 240 research scientists, engineers and support staff and help them deliver value to New Zealand firms and industries and also some international firms and industries.

R: This next question is just for our recording but what is the name of your organization?

RT: Callaghan Innovation

R: What does the word microfabrication mean to you?

RT: Making really small things.

R: How does microfabrication play a role in your organization?

RT: So microfabrication is one of the services we offer to New Zealand firms as part of our suit of technical services and it's something that we have particular talent skills and abilities which is mainly associated with people plus specialized equipment which is not generally available to firms and industries. So it's a service we provide.

R: How has miniaturization changed technology changed technology in New Zealand?

RT: I think it's done it quite subtly because basically the miniaturization of things leads to significantly greater efficiencies and a lot of people have using products which have incorporated, but which they might be quite unaware. So the classic example, if you go and get a blood test then you want to get your glucose checked in the good old days, they filled a test tube with blood, sent it away, and you know five to ten days later, you got a result. Now, people just take a tiny spot of blood, put it in a machine and bingo, you get the results straight away. And that’s not something where people are kind of consciously aware about it because it’s just “oh, this is an improvement of technology” but it’s a really good example of microfabrication just changing things for the better.

R: What do you imagine microfabrication to be like in New Zealand in 5-10 years?

RT: Well I like to think there will be greater use of it given New Zealand is dominated by primary industry, we actually have both say, a meat processing and dairy processing a lot and our uses of water and soil and air and that sort of thing. We spend a lot of time and money sampling and testing and dealing with things in that area and the quality is extremely important to our export results. So microfabrication provides the opportunity to basically do that and far more of that in a real-time setting rather than at the moment and sort of take a sample, go away, look at it for a while and that sort of thing and get a result within 8 or 24 or 48 hours.

R: How do you see ongoing miniaturization affecting the future in 5-10 years?

RT: Well I think in addition to the work that’s done in New Zealand, I think we’re going to see a significant increase in it. It’s driven by the fact that people have realized that if you make things small enough, you can start incorporating multiple devices in a single device best exemplified by your cell phone which is a phone, a you know-- So I’m older than dirt. Back in the day, to do the things that cell phone used to, there's a wonderful image, I don't know if you've seen it, of someone standing there with all the first individual devices. So you know, tape recorder, phone, camera, computer, etc., etc. And I think increasingly people are gonna say what else can we do that with? And I think technologies like that are going to, for most people, advance to the point where they're not actually aware that they've got all this technology, they just have a thing that does something that it didn't used to before.

R: How do you think the microfabrication industry impacts New Zealand? Or impacts society in New Zealand rather?

RT: its impact has been quite subtle. It is in the things getting smaller, more things getting available, much faster and more efficient things. It's not yet become a very large industry in New Zealand and it's unlikely to become a dominant industry in New Zealand because our population size. We don't have a huge manufacturing base but actually in the everyday products people use and potentially if our big industries make greater use of it, it will have an impact. But people won't necessarily be particularly aware of it. In that respect, it's like a lot of technology in New Zealand.

R: What do you consider the strengths of the microfabrication industry in New Zealand?

RT: I think it's got, really got great people in it. I think those people have a real passion for what the technology can do. And they've recognized that what we need to do with microfabrication in New Zealand is not what we might do overseas and a good example of that is some work that's happened at Auckland University through Cather Simpson's lab where they're using microfabrication to look at sexing semen which seems like kinda an interesting thing to do but New Zealand's largest industry is the dairy industry and the dairy industry, when you're looking at herd replacements. So this is calves you wanna grow to replace cows in your herd that have gotten too old or not performing well enough. What you really want is your best cows to have female calves. Because if they have bulls, they're kind of no use to you. So sexed semen in the dairy industry has been for a long time one of the kind of holy grails. And microfabrication is actually giving us a way that this is actually possible. And so potentially it's of very high value to that particular industry because New Zealand is dominated by the dairy industry, this is an application that really appeals on a New Zealand setting.

R: So what do you consider the weaknesses of the microfabrication industry here in New Zealand?

RT: Biggest challenge is scale. It's a relatively small industry and a relatively small community so it's getting it to the point where it has enough scale that it can start getting the attention of our bigger industries and being able to service their needs. That's not a challenge that is just linked to microfabrication, it's true for a lot of our research.

R: What do you know about industry clusters?

RT: Quite a lot. Having established several of them.

R: How aware are you of the microfabrication facilities in New Zealand?

RT: I think I've visited at least 3 of them. And I'm aware of the different ones around. So I've been here, Victoria, and Auckland so.

R: How willing would you be to join a cluster initiative for microfabrication and why would you or why wouldn't you?

RT: So I think, and I'll answer this on behalf of Callaghan Innovation rather than just me personally, I think it's absolutely essential. I think, we talked about the big challenge facing the industry that is scale. I think clustering is one of the ways you can increase the effective scale of the industry because if you actually get everyone connected then it operates much bigger. Again, it's a model that's been quite successful in other parts of New Zealand industry. We are a small country, we are quite a geographically diverse country for our population and so anything that either hard wires or connects people is really important.

R: What other industries, I'm just wondering, have also used cluster initiatives that have been successful?

RT: So the ones I'm familiar with with my research background are in the primary industries. We put together a cluster around meat automation. So robots that process in particular sheep in the New Zealand context. We put together a cluster that has grown considerably larger around greenhouse gas research around something called ??? disease which is a disease that sheep, cattle, and deer get and there's been various other ones. In the sort of wider research context, you also have the national science challenges which are not industry clusters but research clusters.

R: Thank you. Are there any environmental concerns with microfabrication and if there are could you elaborate on that? Like what are they?

RT: So from my perspective, I don't think there are any unsolvable environmental concerns but typically in microfabrication particularly when you're etching, things like that you use quite an interesting range of chemicals none of which should be taken orally or anything like that. So you've got to have sensible fabrication design. If you're actually getting down to creating things at a nanoscale, then you need to think very carefully about containment and how you go about that sort of thing. We haven't typically operated down at that level very often but you've just got to take sensible precautions but it's not-- compared to other environmental hazards, I think if you apply common sense, and follow the protocols and that sort of thing, it's reasonably straightforward to contain any environmental issues.

R: What are some of the chemicals that are dangerous that they use?

RT: People use things like fluorides and chromides and really strong acids and bases and that sort of thing. So you've got lots of different solvents, lots of different fairly reactive things. So because you're wanting to-- say you're making a microcircuit or something because you're wanting to etch away copper and that sort of thing using pretty corrosive stuff. But again, if you do it in a fume hood with appropriate protective gear you'll be fine.

R: What types of government regulations affect your work if any?

RT: Just about all of them. One of the things I do, because I look after a section of technical services, I'm also the height site director for the site from basically a hazards standpoint is I get to fill out, we do a survey called Comply With, which is all the different pieces of regulation and are we complying with them. I do that quarterly and I think I have to answer something around 180 questions. I think it's about probably 6 major pieces of regulation but in total it's about 27 different regulations. A lot of them relate to health and safety, those are kind of the big ones, but there's also environmental acts, there's goods importing acts, there's workplace acts, there's intellectual property acts, all that sort of stuff. And then there are a whole lot that relate to just being a good public servant. And we also have to comply with tax and all that sort of stuff as well.

R: What is your current approach to stay relevant in this rapidly expanding field?

RT: Employ the best possible people we can, encourage them to understand what the leading edge is so that supporting them in terms of knowing what is the research that's happening around the world, having the opportunity to go to international conferences and see what's happening. We're realistic, New Zealand spends about .2% of the world's total R&D spend so we don't expect to discover everything here so we need to know what is happening around the world. That's the key.

R: Is your company looking to hire more staff?

RT: Not right at the moment. We're maintaining staff levels but we're not on an expansion mode at the moment.

R: What factors, in your opinion, make it difficult to compete in a global market?

RT: That's a fairly complex question. For us, in terms of research, you've got-- the biggest barrier to people doing research in New Zealand is them not doing research rather than typically doing research with international organizations. Companies which actually spend money on research we're quite comfortable competing with other New Zealand providers or international providers. There may be international providers that are cheaper than us, many are more expensive so it's not really a price issue. The biggest challenge actually is getting New Zealand companies to do research. If you expand that to a New Zealand company thing, what are their big issues in a global market, the big challenge in New Zealand is because we have a small population and a small domestic market companies typically have to move to export at a much earlier stage than organizations in say, Europe, the US, China, that sort of thing. Because our maximum market is sort of 4 million people. If you're in a niche, it's actually very easy to hit market saturation in New Zealand or get close to it. So early on in your product development cycle, you need to start looking overseas. New Zealand companies typically don't necessarily realize that when they start their manufacturing process and what's actually involved in heading overseas markets.

R: I just wanna step back really fast. Can you give any reasons why R&D is so small in New Zealand?

RT: Yes, so again, that would be quite an elaborate answer. You've got several factors at play, one, our biggest industries are primary industries and primary industries are typically driven by production efficiency rather than added value manufacturing and there's typically a lower research spend to achieve production efficiency than to create added value products. Potentially, if you're the dairy industry it's how do you get more kilograms of milk solids of the same land area or the same number of cows rather than what's the really cool things you can do with milk. We also have, because of our small market it's relatively easy for companies to end up in a dominant market position or even in some cases a monopoly position. And there's quite high barrier to entry so for a long time, telecom for example was our leading telecommunications provider and they owned for a while probably 95% of the New Zealand market and when you have 95% of market, it's very difficult for another company to come in because it's very hard to compete. But also, there isn't a huge incentive on you to spend a lot of money on R&D because you've captured the market.

It’s one of the challenges of small economies is there isn’t the internal competitive drive which typically drives R&D. If you’re operating in California and you aren’t selling a state of the art product, you’re going to go out of business because there will be dozens of other companies competing in your space. California as an economy is vastly bigger than New Zealand. Where in New Zealand if you’re the local provider of a particular service, often you will not actually have any competitors in your market. So there isn’t a huge incentive. Those two things are kind of the key drivers. We also don’t have a tax incentive on R&D.

R: Does New Zealand have any regulations against monopolies?

RT: It does because it has to comply with international economics. And we’re a free market so the monopolies are not state controlled. But that often means that we end up in a duopoly. So for instance, all our supermarkets in New Zealand are owned by two companies and so they compete because of the fact that there’s only the two of them. There is sort of competition but basically they’ve established positions in the market. There’s almost a disincentive for one to completely take over the other because then they would be a monopoly and actually they are unlikely to get approval for the takeover. For a third party to try and come in, it would be very very difficult. For quite a while, our power industry was essentially a state-owned monopoly. Now that’s been freed up somewhat. But again, you have dominant providers.

R: Thank you. Kind of switching gear here, what are the main and potential applications of your work?

RT: In terms of Callaghan Innovation as a whole or microfabrication in specific?

R: Microfabrication in specific.

RT: I think that the opportunity for us is in kind of two areas, one is primary industry and we’ve done quite a lot of work with the dairy industry and I think there is real opportunity in some of the other primary industries as well. And the second is working with a small innovative New Zealand firms. Ones that are actually looking to grow industries and that sort of thing. It’s quite hard to predict exactly what they will look like but that’s a matter of connecting with them and helping them develop niche products.

R: So we’re at the end of our interview, thank you very much. Do you have any additional comments?

RT: In terms of the research environment in New Zealand, entities like Callaghan Innovation fill a very interesting niche. In other larger economies, you typically have a university sector that does leading edge research and then you may have institutes or private research providers to fill the space in the applied research and translation of the leading edge research through to industries. In New Zealand, because of the market scale, that's been an area of market scale. Our role is sort of to play that role and I think one of the things that I've long believed is really important is maintaining the breadth of research because we don't know what particular area of research any given company that comes along to us or we discover and go and see will need. Always one of our challenges is having the breadth of research that we need but having the depth for that research to be generally world leading. So it's always an interesting balancing act and so microfabrication is a really good example because I think it's been an area where we've maintained really good quality research but it's taken a while to get the level of industry engagement we're looking at and now we're starting to see that happen but we've needed to take that long term view and I think it's really important for the future of New Zealand that we continue to take a strategic long term view of the different areas of research rather than responding to the short term market fluctuations.

R: Do you know of any other companies or research groups in New Zealand that have interest in microfabrication? And do you know who we can contact and what is your relationship to them.

RT: So yes, we're quite familiar with the other research providers in the space obviously Auckland University and Cather Simpson, there's a research group at Victoria and Otago but Andrea knows them a lot better than I do.

Interviewee: Vinny Campbell

Interviewer: William Boyd

Organization: Callaghan Innovation

Location: Asteron

Date and Time: 22/1/2016 11:30:00

William: What is your name?

Vinny: Vinny Campbell.

W: What is the name of your organization?

V: Callaghan Innovation.

W: And would you like to remain anonymous? We can ask this question again at the end after...

V: Yeah, ask that at the end.

W: Which part of the microfabrication industry are you personally involved in? This is supplier, manufacturing, research, or student.

V: You mean, me as in Callaghan Innovation?

W: You as an individual.

V: Individual. So, as an individual, I am a connector for New Zealand business. To connect them with our microfabrication people in Gracefield. So that's what I do. If they need the microfabrication expertise, I connect them with Gracefield, our scientists. That's it.

W: So, I guess we've had someone that's pretty similar, the commercialization manager Hamish. And so I think he was a supplier. I think that's what we considered him to be.

V: A supplier. Of microfabrication services, yes. That's right, so I'm a connector in Gracefield. Supplier, yeah, we're suppliers of expertise I guess.

W: All right, cool. And what part of the microfabrication industry is your organization involved in, given the same…

V: Supplier. A supplier of services, supplier of expertise, and supplier of equipment. All that sort of stuff. And not only that, we don't just supply that stuff, we sort of help businesses I guess find solutions to microfabrication.

W: What is your job title?

V: Maori Business and Relationship Manager.

W: In your own words, what is your job description?

V: My job description is two-fold. Like I said, one half of my job is to enhance staff capability of Callaghan Innovation, about 350-odd staff, to get them more confident, more capable, more skilled, and to work with Maori. To work with the Maori business, Iwi trusts and corporations. The majority of our staff don't know much about Maori or had much interaction with Maori, but of course the Maori economy is huge potential and it's emerging. It's getting bigger and bigger so our people, our services, and our business needs to be fit for Maori, basically. So my job is to run different initiatives, activities, to raise the confidence, capability, to engage. The other half of my job is customer focus. So my job is to go out to the Maori economy, areas of the Maori economy, bring them into the Callaghan Innovation fold so they can access our funding, they can access our expertise, all that sort of stuff.

W: Thank you. What does the word microfabrication mean to you?

V: To me personally it means sensing and automation. That's about all I sort of - yeah, that's about all I know about microfabrication. And all I know is it's, you're dealing with stuff you can't even see a lot of the time. So I've been through the facility at Gracefield, seen all the stuff. Amazed at what they do, it's amazing. But my own experience and knowledge about microfabrication is quite low.

W: Given your background, if you feel that you don't have a good answer for any question, feel free to pass.

V: Cool.

W: How does microfabrication play a role in your organization?

V: Again, I'll sort of - same as a similar answer before. We supply the use of our equipment, we supply our expertise to businesses that are looking for solutions where microfabrication might be able to help.

W: How has miniaturization changed technology in New Zealand?

V: I guess you know, like I said with my limited sort of knowledge, in what I can see it's bought New Zealand. You know we're still lagging behind a lot of other Westernized countries like the States and that, but it's sort of bringing us up to speed with all the latest innovative stuff. For me, from my own observations, it's about - miniaturization has ensured that the public are getting better services now, making the shopper or the customer's experience a lot better.

W: What do you imagine microfabrication in New Zealand to be like in 5-10 years?

V: I envisage it to be a substantial increase of what it is now. Maori have typically come from the primary sector: fishing, seafood, and all that sort of stuff. Forestry, all that sort of stuff. But more and more I think innovation is sort of coming more and more into vogue, if you like. Into fishing, we need to innovate, we need to get smarter, we need to compete. So it's taking the Maori economy a little longer. But I think, in terms of the Maori economy, I do think they're going to be substantially bigger in 5 to 10 years. And I do think it'll be reflective of New Zealand as a whole. So yeah, way more substantial than it is now.

W: Thank you. How do you see ongoing miniaturization affecting the future in 5-10 years?

V: Again it goes back to definitely increase quality of life. You know when you're talking about positively - you know, that microfabrication could positively affect medical devices, a whole range of things - I think, from the little I know, microfabrication could potentially (it may already do) go across all industries in New Zealand. And that can only innovate, make things better, make the shopping experience better, make, you know, generate more high-paying jobs, generating more income for the country. So I think overall it's going to benefit us greatly.

W: How do you think miniaturized technology impacts society in New Zealand?

V: Probably deviating it to my previous answer. I think it's improving the way we live, the way we do things, the way business is transitioning into the more innovative sort of areas, industry. I think it's definitely contributing positively and it's only getting better and more people are becoming aware that they need to sort of innovate through microfabrication to compete on a big stage.

W: What are the strengths of the microfabrication industry here in New Zealand?

V: Oh gee, might have to pass on that one. Strengths…. Just let me think about that just for a second. Strengths…. Not really strengths, but potential to make things a lot better than it is here. So I'll pass on that.

W: What are some of the weaknesses of the microfabrication industry here in New Zealand?

V: I don't know enough about them, sorry.

W: How do you feel about collaboration with other organizations?

V: I think its key. Whether it's collaboration with different partners here within New Zealand or globally, I think its key. Collaboration's always good, partnerships are always good, relationships. And New Zealand, being here where we are geographically, I think it's - we need to.

W: All right. What do you know about industry clusters?

V: Quite a bit. A large focus of our work in the Maori economy is we develop clusters ourselves. So for instance we have a - within our team, within the Maori economy here - we have an IT cluster. So where we get different business, key businesses, innovative businesses - we get them all in the same room, get the right people, good things happen. They leverage off one another. We take them overseas, they learn different things, they come back, they change their business plans, they've got a new sort of worldview, if you like. So we use clusters all the time. We've got a seafood cluster. We take them all over the world to Scandinavian countries, Japan, just to - we take them as a group, because they're always learning, see what's happening around the world, the latest innovation, see what they need to do to innovate to compete. So we've got a seafood cluster, honey cluster, IT cluster, medical device cluster. So we get key people together, get them all on the bus with a common goal - shared goal - and off we go. We start the process - get everyone together - we start the process, we drive it for the first bit and then the goal is they start driving themselves.

W: Awesome, thank you. And feel free to pass for this one. How aware are you of the microfabrication facilities here in New Zealand?

V: I know they're big in unis/universities, Crown Research places, and us. That's all I know. No doubt there's some in business somewhere, but universities I know are big on microfabrication. Yeah that's about it; that's all I know.

W: How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication field?

V: Me personally?

W: Yes.

V: Yeah, I'd definitely look to be part of that. Yeah, definitely. Again, being in a cluster like that, you'd see up to date stuff, what's happening, you'd see opportunities, I would imagine. Opportunities and I'd get learnings that I could take back to Maori economy, my customers. So anything that can sort of increase the awareness, the knowledge, identify opportunities is good. And that's what a cluster does I think.

W: Awesome, thank you. Are there any environmental concerns with microfabrication that you know of?

V: Not that I know of, but there's no doubt in my mind that microfabrication and all its applications could probably be applied to industries where adverse effects could happen to the community. Yeah I've got no doubt in my mind that it could be applied to industries that do harm to the environment and stuff like that.

W: What types of government regulations affect your work?

V: Government regulations for people, for businesses to get research and development funding from us is a ministerial direction. So there's eligibility criteria for anyone who wants to access our services or our research and development funding. So really we're dictated to by the government who we can give money to and why we can give out that money.

W: How do international trends shape the future of New Zealand microfabrication?

V: It would be a huge factor. Again, in my experience in the Maori economy and New Zealand economy, we look to overseas, I guess, to look at the trends, the new, innovative, cutting edge stuff. And a lot of different industries here, sometimes we're at the cutting edge, we're doing the innovating. But I think my own opinion - and I don't really know - but my sense is that in terms of microfabrication, we look overseas to overseas leaders perhaps. I could be wrong.

W: Is your company looking to hire more staff?

V: Yes, we're always looking. I think, depending on where the New Zealand economy is going, which direction it's taking, we always need skilled people in different industries; microfabrication's one. We're sort of here, Callaghan Innovation is here, to sort of assist business, New Zealand business to innovate. Use R&D so I guess if there's different sort of trends, you know, we might need to bring in people that know about that stuff. So yeah, we're always hiring. Always looking to hire. Particularly around in the sciences, on the technological side.

W: What products does your company provide for the microfabrication industry? Also could be services.

V: I guess our Gracefield site, where a lot of our science sits, they've got all - they've got so much equipment out there, you know. Top of the range stuff. Cutting edge stuff. So we've got equipment and we've got the people who know how to use that equipment. We've got scientists that have been around a long time; that's all they've ever done is microfabrication and that sort of stuff, sensing and automation. That's what they do. Very learned people. A lot of them have doctorates and they know how to apply science. So we've got the equipment and we've got the expertise.

W: What country do you do the most business with?

V: Me personally?

W: As an organization.

V: As an organization? We don't do business as such; we help businesses do business with overseas companies. But what we do have is different partners overseas, so like we've got great contacts, networks within Stanford, Silicon Valley. Not only that, we've got actually networks all around the world. So we take delegations over there, they bring delegations here, that sort of stuff. So we don't actually do business, but we share a sort of common goal which is innovation, research and development, that sort of stuff. So we don't actually do business as such.

W: All right, would you say that you help businesses in New Zealand less or more than businesses outside of New Zealand?

V: We don't do - we don't help businesses outside of New Zealand at all. It's only New Zealand businesses we help, and even if they're here and they're owned by a foreign person or foreign group, we don't fund. So they've got to be New Zealand grown.

W: What factors make it difficult to compete in a global market?

V: I guess less and less these days is the sort of geographical location of New Zealand. For our exporters, it's definitely a downside. I guess the size of our economy, the size of our sort of expertise, you know, the sample size of the sort of expertise we've got here. I guess funding. Funding is definitely one of the factors that make it hard to compete. Yeah, more the size of the economy and the expertise and the money involved. I think that's huge here, as compared to somewhere like the United States.

W: What companies do you supply in New Zealand?

V: Supply with microfabrication?

W: Or services.

V: Or services? Multiple, multiple number of companies. Probably too much to say. But industry-wise, companies in the primary industries, IT, medical devices, farming, the whole range. So our expertise within Callaghan, we cover most industries. So we work with most industries. Where we don't have the expertise, I guess, it's part of our job or part of our mandate is to connect. If we haven't got it, we'll connect. We've got an international team that will connect, Global Expert

Team, they call them. Global Expert Team. So if business comes to us and we haven't got the expertise or we can't find it within New Zealand, we'll go offshore and find it. So we've got a good group that does that.

W: All right, so we just have a few more additional questions just to wrap up. Do you have any additional comments that you'd like to add?

Tyler: Before that question, we were going to ask whether Maori have any cultural conflicts or cultural concerns with high tech industries or microfabrication.

V: Yeah, that's a good question. That's a great question. I think, it's funny, the Maori economy. You've got one half that are very traditional, then you've got the new up-and-coming breed that are all about innovation, all about high tech, all about making money. So I guess there's definitely a sector of the Maori economy or Maori people that believe high tech, microfabrication, all that sort of stuff is just going to take jobs away from our people. I think there's still a lot of work for us, Callaghan Innovation, to educate the Maori people or the Maori economy in particular about the benefits of high tech. When I say I mention duly that the Maori economy is emerging. It's emerging because of high tech, so there's definitely a stream of innovators, entrepreneurs that'll grasp it. But there's always that sort of traditional thing about high tech within Maoridom, is it going to take jobs away? Cultural stuff like, what do you call it, stuff like - anything to do with the body. Like if you're going to clone somebody. You know, that's a no-no because in Maoridom the body is sacred. So if we're using high tech stuff or microfabrication to interfere with the body, it's a no-no in a lot of the Maori sort of thinking. You know, the traditional thinking is the body should be sort of left alone. So even food, when you're cross-pollinating plants or whatever it is, if you're using high tech to interfere with gods/natural sort of stuff, it's a no-no. So that's the traditional sort of thinking, but then on the other side of course you've got the new, innovative, not-so-traditional, out there to make money, out there to get global, and they can see only benefit from it.

T: So do you have any programs or things like that in place to educate the Maori about the benefits of high tech? Because I know you…

V: Yeah, we use clusters to do a lot of that. We attend, well we're very outward facing. We attend a lot of the Maori leaders' forums. We attend a lot of events. We get Callaghan Innovation's visions, our services, our products, we take it out there. We take it out to the Maori economy as a whole. One of the key factors of success for the Maori economy is that as we bring in companies and businesses to Callaghan Innovation and they see the benefits of it, one of the key success factors are that it's these businesses that are going out to the Maori world and saying "hey, listen! Go to Callaghan Innovation. High tech, this is what it's done for us, this is what it can do for you. Go to Callaghan Innovation." So we need all these different companies to go out to the Maori economy. That's one of our biggest sort of tools we use to bring people in and learn about high tech, the benefits of high tech, how to innovate, benefits of innovating.

T: So when you say you go out to the Maori economy and talk to them about this, are you talking about just that half that's already interested in the high tech and you want to…

V: No, no.

T: You're talking about the other half?

V: Definitely, because sometimes you get those different halves, sometimes, especially in the Iwi trust or in corporation space, they all go hand in hand. You know, they might have the two thoughts, two different thinking patterns but they're all in the same organization so when the decisions are getting made whether they're going to spend any money on research and development, there's a lot of discussion that has to take place. So it's no use us only talking, preaching to the converted. We need to take that message to the whole sort of Maori world, that sort of thinking. And Hemi, you know our general manager, that's sort of his expertise as high level networks at the highest levels.

T: So I'm sorry, one more thing. So when you're talking about that you're looking to hire more people, are you specifically looking for Maori or are you just looking in general for anyone who's interested?

V: In general. But we are - the Maori economy is emerging and we're getting busier and busier so we need more Maori on our team that we can sort of access and really get into the Maori economy, get the penetration. Because we're only touching the surface at the moment. Innovation, in terms of the Maori economy and innovation, there's still very much emerging but the potential is there. We haven't even really - we haven't penetrated in yet. We're just skimming the surface.

T: So why specifically do you think it's important that you reach out to the Maori?

V: Well, you know, we sort of believe here that New Zealand can't survive on primary industries alone. You look at the milk, the dairy industry here, s***! It's bloody terrible! It used to be huge, and the forestry! Everyone's doing dairy around the world now, everyone's doing forestry, kiwifruit. So we need to use innovation, microfabrication, to compete, to keep us up there, but yeah.

T: Because I know there's like - well when we were doing our preliminary research, we were finding that there's a lack of skilled labor in New Zealand and we were kind of thinking that the Maori is more of a pool of labor that could be accessed.

V: Absolutely mate. Part of our mandate here at Callaghan Innovation is starting to build a pipeline of young Maori students, to get them into the innovation and technological fields. Now one of the initiatives we do is we take - we did a pilot last year, we took twelve, thirteen, fourteen, fifteen year olds to Stanford, Silicon Valley to open their eyes to what's out there mate. Open their eyes to what's happening around the world. And that's only a start. We took twelve, we're looking to take a hundred this year for that specific reason is Maori, generally, they go into the sciences or technological fields very, very little. You go to the universities, you go to the colleges, very few Maori take up science for whatever reason.

T: Do you know any reason?

V: I guess traditionally, you know, over the last couple of generations, Maori have tended to sort of work in the laboring jobs. Freezing works was a biggie - the meat industry. Farming. All the primary industries: fishing, seafood, all those sorts of stuff, laboring jobs. Because you know, like it or not, Maori here, we're sort of a minority now. And just like a lot of minorities around the world, fifty percent of our jails are filled with Maori, that sort of stuff. Their health statistics are down. Education's got a lot to do with that. We're sort of turning a corner now. We went through a couple generations where education wasn't the most important thing. It was getting work. You know, go to school, leave as soon as you can, get a job. That thinking is changing for Maori. We're getting more and more Maori in universities, but still very few are taking up the sciences. I don't think science has been naturally or traditionally been big on the agenda for Maori at all. Maori have traditionally been good at working with their hands: good operators, good machine operators, that sort of stuff. Science has never been big. The other thing that I'll also mention as well: a lot of Maori schools throughout New Zealand, they only learn in Maori. Full immersion Maori. So it goes back to the teachers in each of these, how skilled are they in science? There's very few Maori teachers in science and math. That's got something to do with it. So if you've got a rubbish teacher that doesn't inspire you, that doesn't push you that space you're never going to do. So a lot of our people, they go on to be lawyers, accountants, a whole range of things, but they avoid science like the plague. And that's because - and I'm a firm believer that that's because - they've never been pushed in that direction. You need people to inspire you to do that sort of stuff. The parents don't push it because science was never big for them. "You go to Uni. I want you to be a lawyer. I want you to be a doctor. I want you to be an accountant." Very few parents are pushing them in science: “you’ve got to be a scientist.” That doesn’t happen. It’s a generational thing, it’s never - the last couple two or three generations, science has never been a priority.

T: So you’re saying that they’re not interested in it because they’ve never been interested in it?

V: Never been exposed to it. They’ve never been exposed to it. So that’s we do a lot of on our team: we take them overseas, we partner with different organizations to pay for it. We’ve got great connections at Silicon Valley and Stanford. So we take them over to see what it’s like, open their eyes. Because a lot of our people, it’ll be the only exposure they get. The education system here, it’s not geared toward pushing Maori that way, into the sciences and technological world. Our education system, by and large, is not geared for innovation. We’re still teaching market stuff that I was learning back in the ‘70s! We’re still teaching the old way. And when we went to the States last time, you listen to a lot of these innovators and entrepreneurs, they say the same thing in America for the lower - they’re not talking about the universities and stuff where you are, the Stanfords. It’s the ordinary education system. I think it’s the biggest barrier to innovation, is the education system. It’s not too dissimilar here.

T: So have you seen a positive response to this, bringing the Maori overseas?

V: Huge, mate, huge. Since we did that pilot we’ve got another hundred in the pipeline that want to do it. And they’re just so impressed with the people at Stanford and the entrepreneurs and the go-getters in Silicon Valley. A lot of those people don’t need to work anymore, but here they are. They’re encouraging our kids to come over. They’re actually saying “you’re Maori. Your Maori values, education, upbringings, you’ve got to integrate that into your innovation.” You’ve got to integrate it because it’s something. And this is - we spoke to [...] Elliot in Silicon Valley, just sold an 800 million dollar company, and he gave out his email to each and every one of the kids: “keep in touch, because in five years’ time when you want to come over and if you need a start in America, I’m your man. But I need to hear from you over the years.” And we met a whole lot of people like that. Stanford, you know, it’s just amazing. Yeah so it’s all about relationships in Maoridom, so we’ve got some really good ones over there in America. So yeah, that’s a pipeline. Maori need a pipeline.

T: So are they applying for this program, or are you just selecting -

V: Well, so there’s a Maori trust. They’ve got about a thousand trustees and every year, through dividends and different things, that one thousand people all got about a hundred dollars each or something as being part of the trust, it's minimal. That's how these trusts operate; if you're on the trust, you get a dividend every year. Some of it's as low as 100, you might get 150, because there's so many trustees. So what this trust did is they got together, made a command decision, they said "right, no one is getting anything for the next five years. We're going to put that money, which is 250,000 dollars a year for five years, to get our people into this pipeline of innovation." So that's just one trust. So that's very unusual; that's a first. Our trusts, our Maori trusts, stuck in the old thinking. If you're in the trust, you get your dividend every year. So with this sort of - we've sort of planted the seed, and it's starting to grow already. We have different people approaching us, "how did you do it? How do we sign up?" So we're in the process now of getting a hundred people over there. Not all in one go, but you know. So people will come to us, "how did you do it? Who funded it? What did it cost?" All these sorts of things. "What do you do over there? What do you get out of it?" So it's having all those discussions, but again, a trust or a business or whatever it might be has to fork up. Callaghan won't pay for it. We can do that hookups, we'll take them there, but it's got to be a partnership.

T: So that was just one Maori trust that did that?

V: Yes, just one Maori trust.

T: How many are there?

V: Thousands, thousands mate. Yeah, thousands of trusts. And again, the thinking is old school. But thanks to Callaghan Innovation, this trust got the opportunity to get some of these kids - so what happened is that this trust, a lot of their beneficiaries, a lot of their sort of people are involved in the school. So here's the school, this is the organization. So a lot of the kids, grandkids, and all that sort of stuff go to the school. So they're quite happy for them to put their money into the school. And so what the school did is they held a competition, a science competition, and they picked twelve people, twelve kids to go on. So they had to do something about it, they had to do a sort of project and they had to present that project. So the twelve best people got the job. Yeah so, you know, it might not work the same for these other - they might just pick twelve people.

T: Awesome, that was kind of long but I wanted all that information, so that was good.

V: All good, all good.

T: So, any other comments?

V: I'm just really, really - we've got to change our angle, our thinking, Maori. We've got to change our angle, our thinking to help ourselves. Government's not going to give us money to do this.

Our people need to think differently, I guess, in some respects. I'm a great one for tradition. We need to hang onto our traditions, our language in particular. But on the other hand, we need to move with the times. We're just huge on giving our kids the exposure, the opportunity to learn about science. If they don't get exposed to it, they're never going to take it up.

W: Thank you. Do you know of any groups or people that may have interest in microfabrication?

V: Any of the sort of industries that I spoke about before, and the only stuff I know about microfabrication is through businesses, which is automation and sensing. And really, that's about it. The only businesses I know of are interested in robotics and automation and sensing. That's the extent of my knowledge.

W: Do you know of any Maori leaders or anyone in the Maori community that may want to talk with us?

V: Yeah, Steve Saunders from the Plus Group. Yeah, because like I said, a lot of his innovation - he's doing a whole lot. He's in town. He's one of the best innovators that we have in the Maori economy, doing lots of stuff. The other one, his name is Jason Witihera. He owns a supermarket in Auckland and he's one of the most innovative. He's doing lots on sensing and automation so he's one of the most progressive places around. He's always looking for ways he can innovate his business. It's a hundred million dollar business.

T: Do you have contacts for any of those people?

V: Yes I have. I haven't got them on me, but I can get them.

Interviewee: Volker Nock

Interviewer: William Boyd

Organization: University of Canterbury

Location: Christchurch

Date and Time: 3/2/2016 15:00:00

William: May you please state your name?

Volker: Volker Nock.

W: And your institute?

V: It's the University of Canterbury, Electrical and Computer Engineering Department. I'm associated with the MacDiarmid Institute as well as the Biomedical Interaction Centre.

W: Which part of the microfabrication industry do you personally consider yourself involved in? This can be supplier, manufacturing, research, or student.

V: Research.

W: And which part of the microfabrication industry is your organization involved in, given the same options?

V: Research and education.

W: What is your job title?

V: Senior lecturer.

W: Could you provide a job description?

V: It involves teaching, research, and administration for the University of Canterbury.

W: What does the word microfabrication mean to you?

V: It means the fabrication of devices for whatever use that contain dimensions, as you said, below a millimeter. Typically in my field, talking about hundreds of micrometers. It's mostly microfluidics, so we would not be looking at anything smaller than that.

W: How does microfabrication play a role in your organization?

V: Certainly it's part of our teaching curriculum. I have a fourth year course on nano-engineered electronic devices which also involve microfluidics, that's the part I'm teaching. There's a reasonably large research group based around the nanofabrication facility that we have here that involves, to a degree, microfabrication. Even though it's called nanotechnology, there are several people involved from physics, chemistry, biology, mechanical engineering as well as electrical and computer engineering. So it's both teaching as well as research.

W: How has miniaturization changed technology in New Zealand?

V: That's a good question because New Zealand, as such, doesn't have a microfabrication industry yet. There's a few companies that are using technology based around microfabrication in terms of sensors and components, but certainly not as a dedicated industry as far as I'm aware. It's mostly in sensor development and device fabrication in terms of measurement devices or analytical tools other than microelectronics or some of the other microfabrication industries.

W: What do you imagine microfabrication in New Zealand to be like in 5-10 years?

V: We're certainly going to see a lot more niche applications, industries. We already have a few small startup companies or sort of medium term companies that are developing tools around components that are microfabricated and I think that will certainly increase and considering its New Zealand it'll be a dominance of primary industry sensing. For example, potentially, and that's being investigated at the moment, there will be some areas around silicon production considering that the electricity is reasonably cheap and renewable, so I can see that happening. And there's going to be an increase in teaching, so that's a very popular topic as we can tell with our students here, so we'll certainly see more of that as well.

W: How do you see ongoing miniaturization affecting the future in 5-10 years?

V: On a national or global…?

W: On a national.

V: National. It's hard to say on that, based around what New Zealand itself produces or what we get as imports from overseas. It's certainly affecting daily life and such, as it affects any country. But like I said, we're probably going to see a lot more applications in primary industry and we'll certainly make improved products that New Zealand is very specialized in. We're talking about anything from food production to dairy farming and there's a lot of biosensing applications there that are being worked on at the moment and certainly down the line in ten years. I can see that spreading out to farms and some of the big companies that work in that field. Certainly very interested in it.

Tyler: Are there any specific primary industry applications that you can think of?

V: Well, we're not doing any specific ones here that we can talk about. My colleagues in Auckland, they're working on sensing components of milk and separation of milk for analysis. There's a few projects in the department where it's about tracking invasive species, so you use miniaturized sensors for those as well. Those involve many primary industries, but there’s quite a strong field of applications in terms of nanoparticle detection and synthesis as well. So there’s an industry around it here already; one company manufacturing the tools and a lot of people, at least at the university level, producing particles that have some form of functionality.

W: How do you think the microfabrication industry impacts society in New Zealand?

V: I’ve had the pleasure of being part of the MacDiarmid Institute for the last ten years now, which is obviously not industry but a research center. And we’ve seen a lot of interest from the public in the last ten years through science outreach that we run as well. So people are very open to the technology as far as I can tell and they can see the potential in terms of how it’s impacted other countries of similar size because one thing New Zealand has trouble with is competing with expensive industries where you need a lot of capital investment, just by the fact of the size of the country. But yeah, if you can get into those niche applications, I think that’s what the public sees as one of our positive aspects there, if it improves the quality of life.

W: What are the strengths of the microfabrication industry here in New Zealand?

V: its custom designs certainly, which is why microfluidics has been reasonably popular. Not so much microelectronics because that costs a lot to establish. Specific biological applications that drive biosensor development, that’s what has been a strength here. So yeah, its small scale, small series of devices at this stage but with the view of establishing an industry in the long run. But it’s certainly focused on the niche rather than the bought.

W: Also, what are some of the weaknesses of the microfabrication industry here in New Zealand?

V: Well the main weakness is there’s not a lot of industry. It’s quite spread and quite diverse so there’s no industry as such. There are a few companies that have products that involve microfabrication, but I wouldn’t call it an industry as such. The problem tends to be capital investment from the research all the way to commercialization. The ideas I think are here, but it’s how you put that into reality, that’s what’s missing. You don’t have the same access to the funding that you have in Europe or in the US.

W: What do you know about industry clusters?

V: In New Zealand?

W: In general.

V: In general. I was trained back in Germany so I have the knowledge of that clustering that you have in Europe based around companies like Bosch and Siemens and the strength of those. You can certainly see an advantage in having those clusters. Again, it's an economy of scale. There are attempts here to cluster those companies, the small ones that we have, to get more leverage for them internationally, but I see there's a long way to go with that.

W: How aware are you of the microfabrication facilities here in New Zealand?

V: I would say I'm very aware of them. Again, the majority of all the players are centered around the MacDiarmid Institute and everyone that works in at least the research side of things, we know each other by personal contact. Pretty much I've visited all the facilities that we have, not all the companies but certainly all the research facilities. I don't think there's a very good exchange between all of them. There could be a better exchange in industry; there's certain companies that work in the field but we haven't got any contact with.

W: How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers for microfabrication? And why or why not?

V: I'm certainly very - I'd be very willing to join one. I did my Master's thesis in Sweden and Sweden was going through a process at the time where they were looking at how many proper cleanrooms at university level they can afford for the country. I mean, it's a similar size country, but they were maintaining an excess of seven different universities and were looking at restructuring to have three that are based geographically sensible around the country. And I think something like that in New Zealand would make sense. If that involves industry as well, that would make even more sense. How you could do it, I have no idea because everyone wants to be close to the center. Certainly it would be a positive thing.

W: Are there any environmental concerns with microfabrication? And if there are, could you give any specifics and how they are dealt with?

V: Based on the experience with our own lab here, there are certainly a lot of chemicals and materials that you use that are environmentally sensitive, at least during the fabrication and device manufacturing stage, as well as during the end of life of the devices. In our lab, we have everything in place according to the New Zealand law, so all the chemicals are being collected and taken to appropriate companies. This, as far as I know, no end of life policies are under any of the potential devices. And for the MacDiarmid Institute, we have started the discussion on nanoparticles because that's obviously one of the big worries that the public has. I'm not aware of the legislation at the current state, but we see the government agencies are aware of the problem and we are, as researchers, certainly aware of it as well.

W: What types of government regulations affect your work?

V: In particular here in the facility that we have, it's obviously the hazardous chemicals. A lot of them are tracked and controlled through various agencies. A variety of my work involves living organisms, it's what we call physical containment. It's regulated through the university and the Ministry of Primary Industries that track the organisms depending on the grade of organism that you use. So those are the main legislations that we adhere to.

W: Actually this is a question a little bit before: How do you feel about collaboration with other organizations?

V: I would say that's one of the main advantages of New Zealand, that there's a very good collaboration and no hidden competition between the different clusters or the different colleagues, at least as far as I can tell. This was probably different before the MacDiarmid Institute, the Centre of Research Excellence was established because the universities were competing, and they still are competing, but on the level that we're working at the moment there's perfect collaboration. You know everyone that works in the field in the country. You know who to go to. That's something that - back in Germany I would've not known who to go to. But here that's certainly a lot better both on the university level and national level.

W: What is your current approach to stay relevant in this rapidly expanding field?

V: Definitely you have to follow the literature. You have to try and stay up to date with that. I certainly limit myself to certain journals in that area, same with the conferences that we go to. Those are very widespread and you have to focus on the ones that you think are relevant. And the other thing is getting collaborators in from overseas, which we're quite lucky here at the universities that we have this Erskine Fellowship visitors program where we can bring people in the field here for a few months to do teaching as well as research with us. And then we organize our own conferences through the institute as well, international conference every two years which is one of the main ways of keeping up to date.

W: Is your organization looking to hire more staff?

V: I can't speak for the university. The department at the moment is certainly not hiring anyone in microfabrication other than postgraduate students and postdocs, but that depends on funding, if you can get a research grant. We're not hiring any staff in this area. There's three of us currently in the department and I don't see the electrical engineering department expanding in the field at the moment.

W: What factors make it difficult to compete in a global market?

V: There's certain problems that New Zealand has based on geography as well as, as I said, access to financial means to develop technology further. The competition about research funding that we have at the moment again limits what you can do with research. But to compete internationally, it's mainly the fact that once you have developed the technology, it's finding someone that funds the next steps and that can be difficult in New Zealand.

W: What are the main and potential applications of your work?

V: So my work in particular is, there are several streams to it, but there are a few biosensing applications that I work on. At the moment, most of it is aimed at enabling other academics in research of the sensors that I've built, cannot see many of them going into consumer product as such. They tend to be lab based analytical tools and will enable biologists, chemists, other engineers to do something different that they couldn't do before with current technology.

W: How much money does your organization spend yearly on Research and Development?

V: I have no idea what the university budget is for R&D. The university itself doesn't tend to spend money, so it tends to be external grants. There's a limited amount that the university spends and all of that has to come out of fees. The majority will be based on grant money that academics apply for. I can't give you the latest numbers.

W: How many people does your organization have on staff? This is in general.

V: The whole university?

W: The department.

V: The department, I think we're currently 20 academic staff and three of them are involved in the nano/microfabrication work. That's teaching staff. There's two technicians in the facility that we have, permanent. I don't have an overview, but I think there's about four or five postdocs there at the moment and around 30 PhD students that are interdepartmental. So not all of them are electrical, but they're users the facility. And there'll be probably three or four companies using the facility at any given year.

W: Can you speak for any of the other departments? I know you mentioned biology and physics and chemistry. Do you know how many staff they have and again how many specifically for microfabrication?

V: Yeah. For example, biology, if they would require microfabrication for any of their projects, they would come to either myself or Maan Alkaisi. So they wouldn't go directly into the lab. Physics, there's two academic staff that would be directly involved with the lab. Chemistry, I think just two or three that directly have students in the lab. Anything else would go through us as a facilitator of the staff using the facility themselves.

W: Do you know how many, on just a rough estimate, how many staff the chemistry and physics departments have?

V: I would have to point you to the university website.

W: All right, so we just have a few more last questions. Do you have any additional comments that you'd like to add?

V: Yeah, I think the one comment I made about my time in Sweden, judging by the title of what the interview was about, whether I see the space for clusters and I certainly do see it, but at the same time I think we already have the clusters that you could have geographically without anyone wanting to say they don't want to travel too far. It would be very nice to have one dedicated, proper cleanroom cluster that you could send jobs to. Some type of foundry which other countries have, other universities do a bit better with. We're sort of associated with the Australian nanotechnology initiative and the nodes they have. So we do have an agreement that we can use their facilities, but again because of the distance you don't tend to go and use those facilities a lot. So to facilitate the research that you just want to do and think you want to try, I believe you have to have it in place. You can't be too far away. And something very good about the model here is that you're not restricted as you would be in a proper cleanroom or proper facility where you have to maintain protocols to make sure that repeatability is given. So you have the opportunity here to try things that you wouldn't be allowed to try anywhere else. That's probably one of the advantages.

T: So you're talking about a cleanroom cluster or something? Where would that be in New Zealand, or do you know?

V: Currently the facilities, at least in completeness of equipment are concerned, is Canterbury. There's VUW in Wellington, there's Auckland University, and there's still a facility at Callaghan Innovation (former IRL) in Lower Hutt. So geographically, Wellington would probably be the most sensible if IRL were to continue to exist. I mean, there were some talks about whether that could be a central place that everyone would come to and do their fabrication. Where you had the technical support, we had all the staff looking after the machines, and where the government would invest. But that all changed when it changed into Callaghan Innovation. The technical side was sort of not as important as the commercial side.

W: Do you know of any other companies or research groups in New Zealand that have interest in microfabrication?

V: I can give you the examples of companies that come here and use our facility. Certainly there's Izon Science Limited here in Christchurch that come in and use our facility. We do some fabrication for Aeroqual in Auckland. I think we've done some work for Rakon, again in Auckland. I don't know all the projects; those are the three that come to my mind.

W: And our last question: Would you like to remain anonymous?

V: No it's fine, you can use my name.

Interviewee: Anonymous A and Anonymous B

Interviewer: William Boyd

Organization: Victoria University of Wellington

Location: Wellington

Date and Time: 20/1/2016 11:00:00

Will: And for the record, can you please state your names?

Anonymous A: [redacted]

Anonymous B: [redacted]

W: And the name of your organization or institute?

Anon A: We're at Victoria University of Wellington, School of Engineering and Computer Science

W: Would you like to remain anonymous?

Anon A: Can I make up my mind at the end?

W: Yes, definitely. Alright, so which part of the microfabrication industry do you consider yourselves to be a part of? This can either be supplier, manufacturer, researcher, or a student.

Anon A: I'm going to go with researcher on that one.

Anon B: Yeah, I've always been on the research side of things.

W: What are your job titles?

Anon A: I'm a lecturer.

Anon B: I'm a senior lecturer.

W: Alright, thank you... In your own words, can you give us a job description?

Anon A: Some of the time I do research into lithography, fabrication, microscopy, new field optics...some of the time I teach, give lectures in electronics – analog electronics and digital electronics – some of the time I do paperwork.

Anon B: Yeah, pretty much the same for me, I have the three streams of research, teaching, and administration. My research areas are very similar to Anon A's, a little bit more on the optics side of things. And my lecture area's a bit different, I actually lecture in project management and professional practice. So yeah, so we're probably the same with our job descriptions and with our roles within the school.

Anon A: I think your paperwork is a bit more complicated than mine, at a senior level I think.

Anon B: Yeah, certainly I've got some interesting paperwork on my desk, yeah. Anon A and my research interests actually overlap a wee bit. So we've had an interest in the small side of things, small scale.

W: What does the word microfabrication mean to you?

Anon B: Do you want to go first Anon A?

Anon A: Not really. *laughter*

Anon B: The word microfabrication...literally making things that are very small, often pushing the limits of what can be obtained with current technologies, so I think of things like the integrated circuits, the photolithography, [intelligible] that goes into that. I think also, for my own particular background, of the laser micromachining that I've been involved with. So I have an image of those SEM images of very small structures that have been inscribed into typically semiconductors. So when I hear microfabrication I think about the semiconductor industry with microfab predominantly, though I have had research interests in other materials.

Anon A: I think that sort of....ummm...the fabrication of CPUs that are in our laptops...that sort of thing comes to mind, but also lab on a chip, microfluidic systems.

W: How does microfabrication play a role in your organization?

Anon A: I would say it's the reason I have a job. It is my research. It's what I'm interested in. It's not a huge part of what we teach students here, I mean a little bit's creeping. But it's definitely what the research is all about.

Anon B: Yeah, very similar to what Anon A said as far as the organization is concerned. I don't think that ECS, which is Engineering and Computer Science, I don't think that we do a whole heap of stuff in the microfabrication sphere in terms of the teaching but it's a real driver in research quite often. We're always wanting things that are smaller than whatever we're doing and lighter and working better. And on the research frontier it's certainly an active area, and an active area where we are seeking and receiving funding. So my research is in a little bit of transition at the moment so I'm not quite sure whether I'm going to stay on the microfabrication side of things or not. It all depends on how things turn up, but certainly I have research interests there still at the moment.

Tyler: So you say you don't really teach it very much, but do you have like graduate students who do research with you?

Anon A: Yes, absolutely. And just to clarify "not very much", we do have a third year course taught by one of our colleagues which covers a lot of the basics and from time to time we'll have fourth year students doing honors projects in microfabrication. And there are certainly postgraduates.

W: Do you see, in the future, teaching more on microfabrication?

Anon A: Yeah, I'd love to.

W: Awesome. How has miniaturization changed technology in New Zealand in your opinion? If it hasn't, that's fine too.

Anon A: Do you mean New Zealand technology, or technology in New Zealand?

W: Just technology in general, so it could be something like the phone development, laptop, stuff like that.

Anon A: Look, I think you've got the biggest one right there, the fact that we've got these massively powerful phones in our pockets, that we're no longer using big, bulky desktops and now not even really laptops, it's just little pieces of glass that you carry around with you. It's changing how I work and where I work. Things like RFID tags. I bought some clothes the other day, they had this little tag that I had to cut out otherwise it would beep beep beep everywhere. I don't know if it counts as microfabrication, but what they're doing with the frontier and the milk products. The analyses they run on those and the quality control. I think it's going to make a big difference.

Anon B: Yeah, I'll admit to being a little older than Anon A, and I've seen New Zealand being in a privileged position as a first world nation. We're very close to the top of the heap and technology in New Zealand has benefited over my lifetime incredibly from the advances in large scale integration to very large scale integration to the kind of miniaturization that we have now. That has made significant but often overlooked or, shall we say, perhaps unappreciated by the general public, or the general public are unconscious of the way that microfabrication has permitted devices to be in just about everything they use now. Compact fluorescent lights, LEDs, computers, and the cars that they drive. Anon A mentioned the RFID tags. The whole network of communications with broadband that relies heavily on microfabrication, and not just electronic circuits but microfabrication of optical devices, and just the mechanics of things that connect. The way we take for granted now that we can access web cameras, we can get data from satellites easily, swiftly...it's changed enormously from when I was younger where large scale integration and very large scale integration on chips were providing quite prominent but still very technologically advanced devices that we were running that were special. Where now we're having to...my children were just counting up the number of electronic devices that we have and my seven-year-old was saying "Oh, I have five devices on the table in front of me". It's just incredible because she had one DS, a laptop, a couple of telephones...all of which are now enormously powerful and enormously versatile and provide her with and enormous avenue of ways to avoid doing her household duties. So it really has changed the face of New Zealand and in many aspects that people don't quite appreciate. They feel being available all the time now, to everybody, and they don't quite realize how different it was when you could not contact someone or find out where they were just like that.

Anon A: I don't know if you guys have it back home...a year and a half ago they turned on 4G or LTE.

W: Yeah, we have that.

Anon A: WOW. You know, that's amazing. It means you can, you are connected to as much of the internet as you want anywhere you go. I'll claim that for microfab, not sure exactly how but why not?

W: What do you imagine microfabrication in New Zealand to be like in five to ten years? So this is focused on the technology or the process.

Anon A: Anon B, I'll let you go first.

Anon B: I'm not sure. You know in ten years' time if we follow the track record it'll still just be an idea and we'll be relying on overseas manufacturers who can fabricate things that we want, and we can buy off the shelf. I think that there's certainly an opportunity that perhaps could be explored for microfabrication here. It could go either way. I do know that there have been some advances even in the local area for establishing microfabrication facilities in New Zealand that don't sit within government organizations, so Triontech has – so I read in my local newspaper – bought some space out at Upper Hutt there, the old CIT site which you guys may be aware of. Whether or not that's actually going to continue, it's hard to say. Just over the last five years or so we've seen semiconductor companies like Spitfire Semiconductors bloom and then wither so I don't know where it's going to be.

Anon A: Yeah, I don't think I'm quite as – well, you're pretty good – but I think I'm even less optimistic on that.

Anon B: Funny, someone less optimistic than me. That's difficult.

Anon A: I think anytime you arrange something that needs a lot of capital investment up front, New Zealand's not going to be a frontrunner. We've got some very good IP, we've got some very good people, but I don't think we're – so unless we're exporting IP, I don't see us making a whole lot of new things here, at least not long-term. I mean, we might have a startup that might go overseas when you build out.

Anon B: Yeah, I think we face – it comes down to competition on a number of different aspects that makes it difficult for us to get microfab up and running here. I think it could be feasible and sustainable. I think you'd agree there Anon A that it's feasible; it could be sustainable in New Zealand. But we have some barriers with the low population, low population density, a cultural bias towards dairy and farming for what we do. We don't see ourselves as a nation that manufactures or microfabricates devices. So yeah, and then when you do have other countries that have greater populations and greater investment in the infrastructure, are closer to market, and have those interactions that really seed the drive toward microfabrication, like Taiwan, Japan, America, parts of Europe. I had been working quite heavily in computing up until a little while ago in software and hardware, doing a lot of fabrication there.

Anon A: I think the other thing is that the people we have here I think are very good and we punch higher than our weights, but we do struggle to get enough graduates through the pipeline. And I don't know if that's because there isn't a particularly strong engineering culture here. There's a strong belief that you can fix anything yourself, but in terms of translating that into STEM graduates who then go on to build an industry...may be a bit of work to do.

W: So, I just want to make sure I understand. You're saying that one of the bigger problems that's kind of stunting the growth of microfabrication is just that all of your resources are just spread out too thin? You said you have some really good people and some really good organizations, it's just a lack of resources and capital.

Anon A: I think anything that needs a lot of capital to get off the ground, we're going to struggle just because of the size of the country and the size of the government's budget, for want of a better measure.

W: So if there's a way of combining that capital and those resources, it may have a better chance.

Anon A: For sure, yeah.

Anon B: I think that Anon A's hit it on the head, it's a problem in New Zealand that generally we are under-capitalized both as households and as a nation and New Zealand and the corporations here. But it's one of the things that you might want to follow this up with Andrea or people who actually know but the microfabs center – the National Microfabrication Facility – one of the reasons that that has never really got off the ground was that while there may be some money around to establish it, that then the ongoing costs, which feeds into this use of capital, people couldn't sustain it, couldn't maintain it, so nobody's been able or willing to take the depreciation costs after the capital investment. So it does come down to those issues. There are people who are willing, there are people who are able.

Anon A: Are you guys familiar with the MacDiarmid Institute?

W: He's more familiar than I am.

Anon A: So that's maybe sort of along the similar lines except maybe towards the research rather than the commercial and they came together and said "look, on our own we're not going to be able to do much. But if we pool together as a national group..." they did get a critical mass, and they were able to start buying equipment, and that equipment is located throughout the country and so if I want to do a particular set of experiments, well I need to go to Canterbury or Auckland or even Dunedin to do that, sort of the same way that people will come here to use the equipment that we have and also the stuff out of Gracefield. But I think that's worked reasonably well, as a research organization. Something based on a similar model but for a more commercial may well be...we've got the past experience with MacDiarmid now and I think it's been really sort of a positive experience.

W: So just to kind of follow up, how do you see ongoing miniaturization affecting the future of New Zealand in five to ten years? So, the impact of this technology.

Anon A: If the trend we're on continues where you can work anywhere and at your own pace and you're connected to everybody else all the time that should make it easier to work remotely. If it's easier to work remotely, it becomes easier to share ideas with the rest of the world. We call that exporting IP and hopefully they pay us lots of money for that, so that should benefit New Zealand very well. So, long term outlook positive.

W: Do you have any thoughts?

Anon B: Yeah, I always tend to follow the maxim that the future's always a better place and the history of our civilization pretty much bears that out. There are going to be a lot of challenges to New Zealand with these technologies. We are stuck out in the middle of an ocean which does make a barrier which may be an advantage if things don't go so well and there are some reasons why things might not go so well. We might hit a technological wall. There's been ideas that have been around for quite some time that the current rapid advance in science in general and in microfabrication is not necessarily going to continue and that if we find that we hit, as I said, a technological wall, a set of problems that can't be solved, that we are likely to hit them at the time where advancement in science is vastest. So we may find that we can't go any further than where we are at the moment and we'll have to make do with what we've got. And there are other things, we start to get into some really speculative stuff for singularity, the development of our own artificial intelligence which is definitely where microfabrication is going to have an impact and lead into that. You're not going to have the development of feasible artificial intelligence without some further developments and refinement in microfabrication technologies I would say. So, on another side, we're having some issues with carbon and fossil fuels and microfabrication has a role to play in improving the technologies for renewable resources for electricity, all the way through at both ends. Fuel cells, transportation, storage of energy, but also in generation down at my particular favorites, fusion, but you've also got the other technologies that people are looking at like wind and solar. I think solar are the PVs, the photovoltaics, and microfabrication has been playing a role in there for decades. So I can see that microfabrication is going to continue to transform the way that we operate in New Zealand. It's likely, if we do find ourselves isolated for whatever reason, which is another possibility, if there is a global collapse, that we'd have to make do with what we've got and we're going to have to microfabricate our own stuff or do without a lot of the semiconductor devices that we have. So for our own security it would be wise to have a microfabrication facility, or the capacity to make our own stuff here.

W: In your opinion, what are some of the strengths of the microfabrication industry in New Zealand, if any?

Anon A: Some of the people involved.

W: People?

Anon B: Yeah, definitely the people. And yeah, the people and confidence in ourselves. We are – we have a situational advantage being far away, being relatively low population density does give some advantages to us.

Anon A: But you're used to getting things done without ideal budgets or conditions.

Anon B: Yeah, exactly. A bit of a "can do" attitude.

W: So a little bit flexible, you'd say?

Anon B: Yeah.

Anon A: Creative.

Anon B: Yes.

W: What are some of the weaknesses of the microfabrication industry in New Zealand? I know you mentioned that a lot of the resources are spread out and there's not a lot of capital. Is there anything else you want to add?

Anon B: I think that the biggest weakness is probably the people again, to be honest with you. Not the specific people working in microfab, but more the general population, the image that they have of who we are as New Zealanders. The politicians, for sure; I certainly don't agree with some of their spending decisions. I think 27 million dollars would have been better spent on a microfabrication facility than on a referendum that we're having at the moment. But, you know, we can all say that we would spend 27 million dollars differently. Yeah, I think that there's a tendency with technology in New Zealand for people to have that "can do" attitude for grabbing things off the shelf that other people have made and then assembling it in innovative ways and often, as Anon A said, under constrained budgets. It's one of the things we do pretty well actually, but it does mean that we don't get stuck in at doing that manufacturing ourselves. We tend to be consumers of those kind of manufactured or microfabricated goods. Is that a fair call Anon A?

Anon A: Yeah, I think a general challenge is for us to get – to do more of the high value stuff ourselves rather than exporting raw materials and importing off-the-shelf stuff and plugging it together and say "look, here's what I made" kind of thing.

W: How do you feel about collaboration with other organizations?

Anon B: Happy. It's encouraged here. I think it's definitely in our best interests to collaborate. Anon A mentioned the MacDiarmid Institute which is a really good example of how that collaboration has functioned really well over more than ten years now, isn't it? Much more. And has been enormously productive and been efficient.

Anon A: And the other thing, because we are so spread out, there's not a sense of competition that you're struggling to survive, right? Starts with: there's enough land for everybody and there's milk to drink so we'll be alright. And that means you're less aggressive when you're dealing with people and so you're more open to collaboration.

W: What do you know about industry clusters and how do you see a cluster operating?

Anon B: I know a wee bit about industry clusters, looking from the outside mostly. I've seen at the smallest, almost most trivial scale, the business parks and the industry parks that people have. But I've observed in large industrialized nations the way that industries that rely on each other with supply chains will cluster, will have facilities in the same countries, often in the same cities, or out in the countryside where land is cheap and people are housed and the workers are housed. So it certainly can function, it gives the economy some scale, it seems like a very good idea. It's not something that we have a lot of in New Zealand. We have very light industry here. There are some areas of light industry around Wellington and Gracefield; Seaview is one of them, in point of fact. Another was out in the eastern suburbs. But by and large, over my lifetime, they've dispersed, evaporated. We used to assemble our own vehicles in New Zealand. For example, over plants in Wellington, in Porirua; there was a plant down in Seaview/Gracefield as well. There was – IBM had a big plant there also on the microfab side of things. But that, as I said, has duly evaporated with the trend towards outsourcing these things to nations that are a lot cheaper to do your manufacturing and production. The big one at the moment is China, of course. Before that, there were places around South America, Central America where people go, Mexico of course was doing a lot of this stuff, Taiwan, Japan of course after World War II really wrapped up and are sitting right near the top now, doing their own outsourcing out in the continental Asia. Yeah, so I'm not sure that that situation can feasibly be remedied in New Zealand when you're talking about industry clusters.

Anon A: I think clusters are clustering for service organizations; they share desk spaces and that sort of thing.

W: So you seem to be focusing a lot on the manufacturing aspect of clusters. Are you aware that clusters can also include research, education, suppliers?

Anon A: That's MacDiarmid, really.

Anon B: Yeah, I think the short answer is yes although my view's a little bit biased having come from Callaghan Innovation where we were mentally and before that industrial research limited where our sector was – the high value manufacturing sector. So a weeny bit blinkered in a way, just from history. But of course, absolutely. Clusters can have – there can be other forms of cluster than simply manufacturing. In fact, Auckland has been "great", in quotes, for a financial sector cluster. And there's been a movement in New Zealand around since the '80s in certain areas that New Zealand should be focused as a financial services center for the globe, and that we were going to position ourselves toward that. And that's a form of industrial clustering, if you call finance an industry. They don't really make any – they struggle with it. I'm a bit prejudiced, I suppose. Well yeah, maybe create profits in a way. Yes, by fair means or foul.

W: How aware are you of the different microfabrication facilities here in New Zealand?

Anon A: Reasonably, always discovering new ones, but somewhat.

Anon B: Yeah, I know what – I know the stuff that I've come into contact with personally. So I've been fairly close to it, so I know that there's a microfabrication unit in Auckland at Auckland University because I was involved with a project there. There's a microfabrication unit at Gracefield. That there's one here, a nice cleanroom facility just next door. When it comes to the other Auckland, of course I know about Spitfire Semiconductors, I know about Randy Crockett's contacts that he's had because I was involved with that a wee bit with Triontech. I know that there's the odd bit around that Rakon has some facilities up in Auckland; part of their light industrial area, wherever the heck it is. I've been and visited those facilities and I know that there are a couple others around as well. Who was the guy who was doing the electronics, Tate? I know about Tate.

Anon A: Angus Tate.

Anon B: Yeah, they've had some facilities there. But then I also know that they've been looking to move some of their manufacturing offshore. So I'd say probably better than average as far as my awareness is concerned. Probably Anon A's as well.

Anon A: No, no, no.

Anon B: Oh, don't be modest.

Anon A: That's not being modest.

Anon B: I don't know whether Canterbury have anything, or Otago. No, Otago have been working but the last time I went and visited physics down there, they didn't actually have a dedicated facility and such, they were just active in the area.

Anon A: It's not so much fabrication, it's just photonics.

Anon B: Yeah, it is. They get into it a wee bit. But then it's heavily toward the Bose-Einstein condensates and those type of – anything small, and they get into the quantum optics down there. I think that the most microfab that they get into is actually in Auckland with the Photon Factory of course with Cather. I've worked closely with Cather with the Photon Factory and stuff.

W: How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication field?

Anon A: I see my role in academia. So I would happily support where I can, I would supply as many students as I could, but I see myself here for the long-term.

Anon B: Pretty much the same as Anon A, I've come from Callaghan Innovation into an academic role and that's where I see myself at the moment. I'd be willing to participate, but only so much as it fits with my research. I can't interested as I might be, and I would be interested – I certainly am interested in a lot of these things – I just can't see it fitting in in a really significant way outside of the academic research.

W: Are there any environmental concerns with microfabrication?

Anon B: Oh yeah. Do you want me to talk? I talk enough already. I talk too much. Gray goo, which I'm sure you've heard about. It's one of those grand fears about nanotechnology that if you have self-replicating devices, whether it be nanorobots or whatever, that they get loose and start changing the environment that you end up with gray goo, because it's all been changed. It's basically the idea of a Von Neumann machine gone wrong. They make copies of themselves and they can't be stopped. That's a potential hazard, for sure, an environmental one. I think on a more pragmatic and realistic scale, I think that there are a lot of environmental costs around semiconductor fabrication and there are other chemical fabrication techniques, polymer fabrications, that mean that you have to manufacture and rely on some quite nasty chemicals, some quite nasty materials that have to be sourced from somewhere. They have to be mined, they have to be refined. All of that stuff takes energy; energy costs – has cost to the environment. You're also talking about discharge of a lot of the solvent wastes and the other chemical wastes that have to be disposed of somewhere that don't necessarily fit well with New Zealand. We don't have a lot of the infrastructure that other countries have for dealing with that, and we don't have a large hinterland that we can just blast it out. And certainly we don't have a centralized political control that China has whereby environmental costs are irrelevant and we can just do whatever the heck we like to get ourselves from where we are to where we want to be in terms of the development of our nation. I see, rightly or wrongly, China as having a huge – saved up a huge environmental problem for themselves.

Anon A: Yeah, I think the fundamental issues when you go to micro and nano scale and you can take silver and you can put it in a chain or a ring and it's quite inert, and you take it down to the nano scale and suddenly it's antimicrobial. The properties have changed completely. And so I know the Australian crowd, what's the name – the Australian Nanotechnology network have done a lot of work looking at the materials they use and saying "how safe are these? What do we know about them? What are the carcinogenic risks? What are the risks to the environment?" And the answer to a lot of that is probably dangerous; we don't know how or why. So yeah, I mean whenever you're dealing with new materials at scales they haven't really worked at before, there are going to be some risks. Sometimes we don't even know what they are yet.

W: What types of government regulations affect your work? If at all?

Anon A: Health and Safety. And so that's sort of the workplace, what you can do in the lab. Getting the chemicals and raw materials that we need. Shipping is very expensive. Apart from that, I don't know if you've run into red tape.

Anon B: Yeah, there is some direct red tape I've run into, I think you've touched on the two that we come into contact with most often. We're under – we have no exempt here, but there's the Hazardous Substances and New Organisms Act which is a significant piece of health and safety legislation that affects everybody who's working in these fields. The shipping one's interesting because we – there are regulations that make significant costs, financial costs, and significant costs in terms of time and having to deal with the regulations around bringing things into the country. But then there's another layer on top of that which is not our government's regulations that affect who we can get stuff from, and how, and whether or not it can be shipped, and the international agreements around who's allowed to have this particular kind of material because we don't want it falling into the hands of terrorists or whether or not it's deemed safe to transport these days. That kind of stuff, which puts a severe crimp in our ability to do things because we are requiring transport over long distances and it can be quite difficult and some of these things can be quite capricious in their nature. The quintessential example of that that was cited in my previous workplace was that a – I forget who it was – some official in some organization, be it a transport organization or customs, said "we are not allowed to transport this under normal protocols. You have to have extremely high hazardous materials protocols for this because it's radioactive." And the reason that it was radioactive, and I think it was Samarium, was because of the natural isotopic composition of Samarium, had a radioactive isotope and they found out about this. So it wasn't that it was actually radioactive, right? It was just that one of the isotopes in natural abundance of – you know, it's like...but of course you can't argue with it.

W: So, what is your current approach to stay relevant in this rapidly expanding field? This can be cutting-edge research, it can be reading up on other people's research.

Anon A: So I think, apart from the research you do yourself, which is sort of a very expensive way to gain new knowledge, there's also reading the journals and the magazines and everything that comes up on the net. Which is other people's expensive research that you can read very cheaply. And being open to new projects. People come out and say "why don't we look at this." Well I don't know anything about that, but give me a week and away you go, kind of thing.

Anon B: Yeah I'm just maintaining – as Anon A said – maintaining the research interests, keeping abreast of developments as best I can. As I said, I'm in a bit of a transition area so I'm not sure if I want to keep up with the leading edge research. But I'm keeping my eyes and my ears open, so that's probably the best that we can do in our situation as researchers. In a way, the best to keep – for us to keep abreast of the field is to be contributing to the rapid evolution of the field.

W: Is your institute looking to hire more staff within microfabrication?

Anon A: I see what you did there. When do you guys finish? When do you graduate? *laughter* I think we're still looking for staff. I don't know if it's within nanofabrication.

Anon B: No, I can say I think it's pretty obvious from the vacancies that have been advertised is that the School of Engineering and Computer Science is definitely expanding but in the direction of computer science and mechatronics and not microfabrication. So we're not hiring staff who are going to teach in that role or who are going to research in that role at the moment.

Anon A: I don't know if you guys are talking to anybody from the School of Chemical and Physical Sciences?

W: We haven't, no.

Anon A: I'd expect their answer to be different. I'll give you names if you like.

W: Yeah definitely. What factors make it difficult to compete in a global market? Now, as working in academia, this may not be relevant to you. So feel free to...

Anon A: Yeah, I'll pass on that one if you don't mind.

Anon B: Having come from Callaghan Innovation, I have a perception, whether it's right or wrong, but I think the difficulties that we find in the area of microfabrication and competing in a global market are that we have only a small population and that we are an advanced Western industrialized nation, but industrialized in the rural sector, the primary industries sector. And also we're heavily weighted, partly for historical reasons, partly for cultural reasons, we're heavily weighted in that area. And that makes it very difficult for us. You know, we are competing and we are competing well there. It makes it very difficult for us as a nation to overcome the difficulties of a small population and of distance for bringing in resources and shipping out resources to overcome the barrier to transition from primary industries to – whatever they're called – the high value manufacturing area. It's not tertiary industry, is it? Whatever the heck it's called.

Anon A: High value manufacturing?

Anon B: Yeah, I think it's probably HVM, is what its most commonly called these days. To actually get that shift going, I think that is the biggest challenge that we find in competing in a global area. The bar for competition is high already, yeah? And we're just not in that area. So those factors make it difficult for us to compete. There's always somewhere else that have lower labor costs because they are not as well developed as we are, who are closer to the natural resources or even have them themselves. I'm thinking of China and its abundant supply of rare earths and other resources. And of course the land area in China is just huge. And the population is – they have population to spare.

W: What are the main and potential applications of your research?

Anon A: I should know this one. *laughter* For myself, its advanced microscopy. So, giving us new ways to look at, for example, biological samples, viruses, blood work. Way before, you'd need to do a whole lot of processing on your sample before you could get a useable image. This should be able to take a sample, put it down, push the button, and you have a photograph at a large magnification. So it should speed up diagnoses, analyses, make things easier and faster. Earlier, the lithography work that would allow smaller, faster chips and phones, laptops, everything else.

W: Thanks.

Anon A: Pick an area, any area.

Anon B: I've come from...I'm going the way of – the direction opposite of microfabrication so I'm heading towards the fundamental side of things with the research, my research interests I always have done. I can come up with some pet applications for things, but the honest answer is that I don't know where they're going to be applied. Few people do know where things are going to find applications, actually ultimately. Where I have been working has had applications in optical communications because I've been working with materials that have photonics applications, actually in ICT. Another research stream that I've picked up just recently, there's things for catalysts. So, nanostructured materials that have catalytic properties that could be used, you know, applied for any kind of catalytic process, be that in engines or for, as I step in some form of fabrication process. And the other thing that I'm doing actually is pretty much applied, which is doing some optical discrimination of cyanobacteria is what we're looking at in waterways, so that really is on the applied side of things.

W: How much money does your organization spend yearly on Research and Development?

Anon A: Lots.

Anon B: Yeah, it's our reason for existing along with teaching. I guess it all depends who you talk to. What is university for, teaching or research? Both.

Anon A: So I can't give you a number, a fixed number, but...

Anon B: We have significant research income as a university and we're encouraged always to take more. The government, of course, does fund us for our teaching for students.

W; Do you know how much your organization spends on microfabrication in particular? Or is that number also unknown?

Anon A: It would be a smaller portion, but the closest thing to do would be to count the number of academic staff who use the cleanroom, multiply by some nominal salary, and call that a ballpark guess but...

W: Yeah, how many people does your organization have on staff for microfabrication?

Anon A: Let's count Elf, yourself, myself, Gideon. So that's four in ECS. And I would say one, two, three, four, five, and Skips.

Anon B: Yeah, at least, not including students.

Anon A: Eric, Ben, Frank, Natalie, Jonathan. So that's five academics. Maybe fifteen or twenty students. I'm probably missing people, but yeah.

W: Just so we can kind of get a reference, a scale, how many staff are at the organization in general?

Anon A: We have thirty academics in ECS.

W: You can give like a ballpark as well. That's fine.

Anon B: ECP/SCP probably about 25 or so, wouldn't it? Bit more than 20.

Anon A: 500 academics across the university? Yeah, around 500 academics.

W: We are almost done, we just have a few wrap up questions. Thank you for taking your time. It's been very helpful. Do you have any additional comments that you'd like to make?

Anon B: I'm really in favor of the idea. I think it would be great to see the National Microfabrication Center come into being. I think that would be good because I've seen the lack of a dedicated center to have been an impediment to New Zealand advancing in this field. It's actually meant a lot of waste of money. It hasn't been a good way of handling things. So I think that's my comment, biased as it may be.

Anon A: That's a great comment. I'm all out myself.

W: Do you know of any grad students that would be willing to talk with us in the near future?

Anon A: I could ask mine.

Anon B: I don't have any students working in this at the moment. I'm a relatively new staff member, so I actually – to be honest I don't have any students at all really, at the moment. At least not graduate ones. Early. Sure, I think Anon A would...

W: Would you like our email address?

Anon A: Yeah, that would be great.

Anon B: You guys looking for people just in the Wellington region or are you traveling around the country?

T: Well, we will be traveling to Auckland next week for at least a day to talk about – to talk to the University of Auckland and places around there. We're also traveling to Christchurch the next week because we have to interview some people there. But for now we've just been doing people in Wellington and Gracefield.

W: And there are some other interviews scattered in various cities but they're kind of out of the way, so what we've been doing is we've been – we actually have a digital version of this that we've been sending out. And that can lead to phone calls for follow up questions.

Anon B: Yeah, I'm sure you're going to be visiting the microfab center at Auckland.

W: Yes.

Anon B: So you'll meet Brian, isn't it? Brian Williams? Is that right?

T: Brian? Is it spelled B - ? I'm not sure?

W: I don't think its Williams, I think it's O'Connell? I think – we have a list. I'd have to check.

Anon B: There's a guy who's managing microfab, or was managing a microfabrication center in the last six or some odd months. It might have changed, but Andrew Best is the guy...

T: Yeah, we've talked to him.

Anon B: Yeah, so Andrew has close connections with the Auckland people. And the –

Anon A: Sorry, you mentioned keeping things anonymous?

W: Yes.

Anon A: Can we please?

W: Yeah, definitely.

Anon B: Yeah, I think that would be good.

W: As long as it's anonymous.

Anon A: You got it.

W: Do you mind if we use the name of your institute?

Anon A: I think that's all right.

Anon B: Yeah, unidentified researchers within ECS. *laughter*

W: All right, that is it. Thank you very much.

Interviewee: Anonymous C

Interviewer: William Boyd

Organization: Shamrock Industries

Location: Christchurch

Date and Time: 3/2/2016 10:30:00

William: What is your name?

Anonymous C: [redacted]

W: And what is the name of your company?

Anon C: Shamrock Industries.

W: What is your job title?

Anon C: Managing Director.

W: Which part of the microfabrication industry are you personally involved in? This can be supplier, manufacturer, researcher, or a student.

Anon C: Yes, well I wouldn't - depending on what you want to describe as microfabrication, you might want to elaborate that more as a definition for us so we can make sure that we're on the same page here. But I guess we wouldn't really see ourselves in being in microfabrication, to be frank. But we do work with universities and research centers who have interest in that field. So it could be that we will complement them as a supplier partner with the services that we provide. So the short of it is I wouldn't say that we were in microfabrication as we currently are. Yeah, the closest we get to that is because of the association we have with universities and research centers to support them with their development projects. And Callaghan, of course, is one of those institutions.

W: Sure, so I'll just quickly give you the definition that we're using for our project. So by microfabrication, we mean miniaturized structures or devices with features that may be smaller than a millimeter.

Anon C: Which we're certainly not involved in, at least not making anything smaller. We machine to obviously finer tolerances, but not usually make component parts that are of that size. So I guess the likes of Rakon in Auckland, do you know? They would be very much in that space.

W: So, could you give us a job description for your job title?

Anon C: And I guess that's where we're a supplier partner to Rakon. So our relationship is supporting those that are in microfabrication, but we're not microfabricators ourselves. So that's the nature of the relationship we have. Sorry, my job description? Managing director. Well obviously as manager, I have the oversee of managing as in the general manager of Shamrock Industries. And I'm also the principal owner of Shamrock. And so that's the nature of my directorship.

W: What does the word microfabrication mean to you?

Anon C: Well, microfabrication would involve manufacture of something, as you've already elaborated, very, very small in nature. And I guess we would tend to see that, for example, in the electronics industry. Possibly in the likes of chemical etching industry. Yeah, certainly microfabrication is not something you would customarily see in our manufacturing space. While we do do precision engineering and we do go down to fine tolerances of just microns, we're not making micro products.

W: So moving on, how does microfabrication play a role in your organization?

Anon C: Well, we're very limited because as I've just explained, we're really only on the fringe of this industry as a support partner to those who are directly in it. Yeah, I guess in our case, we would seldom use such products in anything that we ourselves are producing, but we certainly have customers who do and Rakon is a good example. And certainly when it comes to sensing, we do quite a lot in the way of bio, or in the biomedical area, with devices and instruments and sensing is naturally very much used there. But at this point in time, I don't see microfabrication as being something that we would participate in ourselves. It's a whole specialist field of its own and unless there were some change in our market that would move us for some reason into that sphere, then I don't think it'll be something that we would participate in. But we would certainly, and already are, involved with people who are.

W: How has miniaturization changed technology in New Zealand?

Anon C: Well, it's opened up a lot of - we're looking at one of these, for example. *holds up cell phone* Miniaturization has just allowed a whole world of development to take place and products to be produced that fifty years ago weren't barely dreamed of. Yeah, so I guess in a nutshell miniaturization has allowed firstly things to be scaled down in size from the ones produced. But it's also allowed products to be developed that weren't even around in previous times. And as a consequence of that, you've now got all sorts of apparatus that are used in anything from the home environment through all sectors of industry that weren't there before. It's also enabled the development of a lot of other new knowledge and outcomes from that new knowledge that wouldn't have been possible had this miniaturization taken place. So it's been, if you want, disruptive in the sense of just how much it's transformed the world in which we live today.

W: What do you imagine microfabrication in New Zealand to be like in 5-10 years?

Anon C: To be honest, it's not something I've given any real thought to. I mean, you can only imagine that it's a field that's going to grow and develop. You know, what New Zealand might be in five or ten years, I really don't know. All I can say is that it's going to have a greater presence and usage than it currently does. And it may have some disruptive impact as well depending on what's produced. I mean, the iPhone alone you'd pretty much have to say is a disruptive piece of technology in the sense of the change that that has brought about the way we do things, from even where we were immediately pre-the-iPhone. So it's quite on the cards that other devices are going to come out that'll have the same sort of advancement and disruption to our current practices as well. But what they are and what impact they may have, I don't know. I'm not that active in that field to really be able to comment. But you would certainly have to project that it's going to be an ever-developing sector and that there will be more advancement and quite probably more disruptive advancement that'll come from it.

Tyler: So by disruptive, you just mean it like changes the way -

Anon C: Well, significant change. There's sort of incremental change, like from one iPhone version to another. That's not disruptive. But I think the iPhone is disruptive because we went from PCs to laptops, but the iPhone now is all of that and so much more in one device so you don't need a landline phone, you don't need a laptop. The advancement that's being made with the iPhone has been disruptive and has displaced a lot of technology that was being previously used and it's opened up a lot of new opportunities that weren't previously there. That's disruptive, it's got to be like a game changer. Otherwise it's just incremental. And I'm sure that in this microfabrication world that you're going to see both happening.

W: For any future questions, feel free to pass if you don't feel like you know…. How do you see ongoing miniaturization affecting the future in 5-10 years?

Anon C: Well I can't really say much more than what I've said there now, that it undoubtedly will. It's going to have a big impact in all aspects really. I think it'll have an impact on our personal lives. It'll have an impact on industry. It'll have an impact on research. It'll give us access to knowledge and information that we don't presently have. It's going to open up new opportunities. Yeah, it's pretty exciting, I would say, in terms of what it's going to bring about. No doubt there may well be social consequences as well. It’s a bit like technology these days allows people to live a lot longer and they’re projecting now that it’s not too far away before people will be living 120 years of age. But then the other side of the fact to that is that next to obesity, the next biggest health issue in the world will be depression. So yeah, so there’s always the upside and downside of these things.

W: How do you think the microfabrication industry impacts society in New Zealand currently? If at all?

Anon C: The industry or the products from it?

W: I’d say the products from it.

Anon C: Yeah, because the industry is like a Rakon, so it creates employment and that’s great. The industry produces these products that we’re using in our everyday life. So the question was how does it -

W: Impact society in New Zealand?

Anon C: Well, probably the biggest thing has been communication. If you look at the likes of the iPhone and, you know, you’ve got all of the apps that come out now that can be used. If you look at the impact that’s made on communication, being able to link together. That’s probably my thinking of the sort of biggest - and that’s good and bad, I’d have to say. The bad things is you get these young fellas that have a party at home and the next thing, they’ve got the whole of the city around at their door because everybody knows that there’s a party at [redacted]’s tonight. Whereas in my day, I’d probably have to send a letter out to everybody that I wanted to invite to the party. The other thing is, for example, I was recently in Australia with a chap; he was from the UK. He had a couple of mates from the UK that now lived in Brisbane where we were. Hadn’t had contact with them in over a decade, didn’t know where they were other than that they were there. Anyway, the short of it is that he got on Facebook, managed to reach them by Facebook on a Saturday morning, he had lunch with one of them on Saturday and he had dinner with the other on Saturday evening. In my old days, you wouldn’t have dreamed of it. Yeah, so to my thinking, one of the biggest impacts it’s had on society is communication and networking. And there’s just so many apps that you can download to do all sorts of - I mean, have a look at my two sons...the things that you can do now that this sort of technology has allowed is quite awesome.

W: In your opinion, what are some of the strengths of the microfabrication industry here in New Zealand?

Anon C: Well, to be honest, I wouldn't pretend to know a great deal about it, so it's a pretty qualified comment. We know Rakon well. They are one of the top three in their world, so they're a real credit to what they've achieved in that sector. Yeah, beyond that is there anybody else that - any comment you can make? Sorry, the question exactly again was?

W: What are some of the strengths of the microfabrication industry here in New Zealand?

Anon C: Strengths, right. Well the near case, of course the fact is that they're in the top three so they're a world leader, is their strength. The other strength that I would see through them is the fact that they've been able to do very successful Research and Development to put them in that space. And I think that's playing to a real generic strength of New Zealand. We're a very innovative nation and whilst - this is a bit generic and I'm not saying it unkindly of anybody, but the Asians are particularly good at taking something and refining it and mass producing it. That's not the Kiwi expertise. The Kiwis are really good at developing something from a concept and prototyping it and I think Rakon has shown that. And I don't doubt that microfabrication will be a medium that the Kiwis will be able to use to develop all sorts of new and wonderful things.

W: Also, what are some of the weaknesses of the microfabrication industry here in New Zealand?

Anon C: I can't really comment. I guess scale and remoteness from market would feature in that. But yeah, we're not close enough involved; well I'm not, anyway.

W: What do you know about industry clusters and how do you see them operating?

Anon C: Well, we're part of some and industry clusters I think are very merit-worthy. They obviously allow networking and communication. They also facilitate, as a consequence, collaboration. And in that way, they contribute a great deal to the development of the industry, you know, that the sector's related to. But they also contribute to the success of the industry participants because people learn off each other and, also by working collaboratively, a lot more can frequently be achieved than by working singularly. And I guess I have a very good example of that in my earlier career which is related to wool processing industry. And when I was first involved there, this is in wet wool processing which was a big industry here at that time, there was - all the industry members had their own little R&D operation which was in a secret dark room at the back of the shop that nobody was hardly allowed to go near. All very hush, hush. But the short of this is that they decided that they would achieve a heck of a lot more by getting together as a cluster group or an industry group and collectively putting all their resources into one research center which then was the Wool Research Organization of New Zealand. And as a consequence of them pooling all the resources and funding the Wool Research Organization, that organization developed the world leading technology of wet wool processing. And as a consequence, the industry here had a transformational change in their processing technology which made them world leaders and they were able to run rings around their competition. And then eventually that technology was introduced to other processes throughout the world. So I think that's a good example of collaboration, and Shamrock is part of industry networks and it works very well for that sort of outcome. If you want help with something, you can get hold of somebody and say, "look, I'm looking for a bit of support with this." And they say, "Oh, you know, go and talk to (...) or whoever it might be." So, definitely to be commended in my opinion and a lot can be gained from it.

T: Another question we had, but I guess we probably know the answer to it now, is how do you feel about collaboration with other organizations?

Anon C: Oh, well I think it's very merit-worthy and I have to say here in Christchurch it's a real strength that we have. Even in our own sector, like we're in precision engineering, we work collaboratively with others in their own field. Now some would look at that and say, "Well, what are you doing there? That person's a competitor to you, so why would you work collaboratively with them?" But we realize that there's more to be gained for us, and particularly our customer, by working collaboratively in a partnership together than by being completely hands off and having nothing to do with each other. And Christchurch as a city is actually very good at working collaboratively even between companies in the same field, but certainly with others. And Shamrock, as such, is very much in that space. We regularly provide solutions for our client which are achieved by working collaboratively with other key parties. For example, that includes electronic, PCB manufacturers, injection molding companies. And it's through that collaboration that you can provide a complete solution, which more and more is what customers are looking to have these days. So I think it's got a lot to be recommended and I think it's a little bit like what I was sharing with you with the wool industry before. Everybody was very "secret scroll" doing their own thing and achieving bugger-all, but by working collaboratively with their own competitors they achieved a transformational change to the industry which they all benefited from that would just never have happened if they had stayed doing their own little secret scroll thing in the back room.

W: Again, this may have been answered. How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication field?

Anon C: I think I've well answered that question.

W: Are there any environmental concerns with microfabrication? And if so, what are they and how are they dealt with?

Anon C: Well again, we're not in that sector. In some parts of it, there are chemicals that are not so environmentally friendly and even vapors that are produced from the process that, again, are not so environmentally friendly. So that's something that needs to be carefully managed, but as far as I'm alert, it's not a major issue. So I think yes, they are something to be conscious of and it needs to be managed, but it's manageable I would believe.

W: What types of government regulations affect your work?

Anon C: Well it's a pretty broad question. I have everything from tax compliance, if you want, you certainly have occupational health and safety, you have environmental. Yeah, I mean it's a very broad question because the police are here to implement the law of the land and we're required to comply with the law of the land so that's from the government. That's probably taking it broader than you're intending but it's a broad question asked. Yeah, I guess to one degree or another, we're obligated to conduct our business in a manner that is socially acceptable. And what's socially acceptable is dictated effectively by government policy. So I'm not saying that's onerous, not at all. But it's a good thing, I think. I think the one thing we do enjoy in New Zealand is good stability and good ethics about how we conduct ourselves and business so for the most part I would say that the expectations that we have upon us, the compliance requirements that we have upon us, is a good thing.

W: How aware are you of the different microfabrication facilities here in New Zealand?

Anon C: Very limited, as you would have gathered.

W: So we're going to move on to specific questions about suppliers. How do international trends shape the future of New Zealand microfabrication?

Anon C: Well, the problem I have here is that we're not actually microfabricators. I guess the only sample I can think of is if I think about Rakon in terms of their component is used in things like iPhones and GPSs and so on. So depending what new products are brought to the world in a global context, will certainly impact on them in terms of where they should focus and direct their attention to the products that they produce. So if you're going to be in microfabrication like any of us in the manufacturing industry, then you've certainly got to be in touch with where the global trends are and opportunities to make sure that you align yourselves because otherwise you'll find that what you're producing is no longer where the market is and you're not producing what the market now requires. Which is pretty much a sort of generic thing that we all have to be alert to and I'm sure microfabricators will be just the same as the rest of us in that respect. But I also imagine that it's a pretty rapidly changing space, at least in our sector. While additive manufacturing is certainly up and coming threat and opportunity to us, it's developing at a not-too-rapid rate, whereas microfabrication and the products that it's used in, they come and go so quickly that you've got to be pretty on the case and pretty responsive.

W: Definitely. Is your company looking to hire more staff?

Anon C: As we go forward, yes.

W: What products does your company provide for the microfabrication industry?

Anon C: Really we produce tooling and equipment that is used to support their manufacturing operations.

W: What country do you do the most business with? This can be New Zealand.

Anon C: Yes, well New Zealand naturally is our main market. We do export to Australia and to Germany and potentially other parts of the globe because of the fact that we are EM as well as a contract manufacturer.

W: What factors make it difficult to compete in a global market?

Anon C: Well, of course, competing against nations that have lower cost of operation than we do makes it very challenging. That would be the first thing. Obviously the fact that - you know, geographical distance from the mass market is a disadvantage. And it works both ways. Firstly, it's more expensive to get the raw materials here because they come from Asia and we have to ship them all the way down to New Zealand. And then of course the products we produce here we have to withstand the freight and logistics of getting them back to where the market is. So I'd say the first thing is really the competitiveness, the costs of production here versus in other parts of the globe, and geographical proximity. Certainly puts the pressure on you to be pretty smart about what you're doing.

W: What companies do you supply in New Zealand?

Anon C: Well, as I mentioned, we're predominantly focused around the biomedical sector and aeronautical, as in aeronautical tooling. Beyond that, we supply to a number of other industries with tooling and precision manufactured components that they require for their own manufacturing operations. So that's as far as our contract manufacturing is concerned. The electronic manufacturing sector is also a fairly significant customer base to us, as OEM. The beef (...) industry of course is our target market for our boning technology. For the newspaper wrapping machine, it's the newspaper distributors that are a target market there. And for the (...), it's the people that are involved in the paving industry. So we're a pretty typical New Zealand SME, we can't specialize into just one industry sector because the market here is so small. So we start with our nothing, which is essentially precision engineering, precision machining, but we're necessarily involved with quite a range of different industries.

W: So we just have a few wrap up questions. Do you have any additional comments that you'd like to add?

Anon C: Not at this stage.

W: Do you know of other companies or research groups in New Zealand that have interest in microfabrication?

Anon C: Well you asked that question obviously by email before today. I mean, Callaghan who you're sort of effectively working with, I know that your report will be very interesting to them. I suggested to you Photoetch Industries, I don't know whether you're meeting them? They are quite small, but they are in that field. Rakon of course you've already been to. Other than that, well the universities really: Otago, Canterbury, Auckland, I dare say Victoria. We don't do so much with the agricultural universities like Massey and Lincoln.

W: Is there any information you provided that you do not want to be published?

Anon C: Well I guess any mention I've made to other companies or institutions. I don't want to cause any embarrassment to anybody by having that go public. I mean, I don't believe there's any sensitivity there and certainly sharing it with yourself there's no issue. But yeah, we have to be probably a little bit careful about - I mean, I don't see myself as any sort of authority in this field and I wouldn't want it to be projected and anything like that context at all. So, very happy to contribute to your research and your study, but you probably wouldn't really want to have what we shared with you released as any sort of public statement or authority.

W: And just the last one. Would you like to remain anonymous?

Anon C: Well, unless you particularly wanted to use us as a reference. I mean, I don't think there's anything particularly secretive about what I've shared with you. So in the first instance I will say yes. If there's something that you would like to make specific reference to to Shamrock or myself, by all means feel free to come back and say, “we’d like to specifically make mention to you about this” then I’m more than happy to be approached about it.

Interviewee: Anonymous D

Interviewer: Digital

Organization: Victoria University of Wellington

Location: Digital

Date and Time: 11/2/2016 17:03:38

Question: What is your name?

Anonymous D: [redacted]

Q: What is the name of your organization?

Anon D: Victoria University of Wellington

Q: Would you like to remain anonymous?

Anon D: Yes

Q: Which part of the microfabrication industry are you personally involved in?

Anon D: Student

Q: What part of the microfabrication industry is your organization involved in?

Anon D: Research

Q: What is your job title?

Anon D: PhD Student

Q: What is your job description?

Anon D: Research into thin films that allow optical microscopes to image nanoscale objects. The optical microscope would then be able to resolve features that are smaller than the wavelength of light imaging them.

Q: What does the word microfabrication mean to you?

Anon D: Microfabrication deals with creating small (features much smaller than one millimeter) devices that can be utilized by many different areas of society, including but not limited to medical, optical and electronic devices.

Q: How does microfabrication play a role in your organization?

Anon D: Our research is focused on utilizing microfabrication techniques to produce thin films that can interact in very specific ways to achieve our optical microscope goals.

Q: How has miniaturization changed technology in New Zealand?

Anon D: I think that miniaturization is everywhere in New Zealand, from micro-beads in shampoo, cellphones, computers and medical equipment. I doubt that many people in New Zealand aren't using or dealing with miniaturized technology in some way.

Q: What do you imagine microfabrication in New Zealand to be like in 5-10 years?

Anon D: Unless government encourages technological research and development both in education and industry I can see New Zealand maintaining the status quo, exporting microfabrication knowledge rather than benefiting from the entire research development production cycle.

Q: How do you see ongoing miniaturization affecting the future in 5-10 years?

Anon D: I think that medical research will benefit majorly from miniaturization in the next 5-10 years. The possibility of individualized medication and treatment is exciting, as is the development of devices to aid an aging population.

Q: How do you think miniaturized technology impacts society in New Zealand?

Anon D: Health Care, and communication mainly. As medical systems and sensors become miniaturized and noninvasive, advanced patient treatment can be performed allowing New Zealanders quality of life to be improved. As technology improves and communication devices become more advanced, the ability for New Zealand to communicate and trade with the world improves.

Q: What are the strengths of the microfabrication industry in New Zealand?

Anon D: Research facilities in New Zealand are very good. Auckland, Wellington and Christchurch have microfabrication "dust free" laboratories and a number of companies have been created from the research conducted in these laboratories.

Q: What are the weaknesses of the microfabrication industry in New Zealand?

Anon D: I think the main weakness is getting major microfabrication players into the market to boost awareness marginalized.

Q: How do you feel about collaboration with other organizations?

Anon D: Collaboration is fine and encouraged, as long as contributions by individual parties are not

Q: What do you know about industry clusters and how do you see a cluster operating?

Anon D: I do not know much about industry clusters, but I believe they are a group of likeminded organizations based in a similar location that can aid each other through the sharing of information, products and services.

Q: How aware are you of the microfabrication facilities in New Zealand?

Anon D: I'm aware of the research organizations in New Zealand, and individual business most of which have spun off from research projects. I highly doubt this knowledge encompasses the entire industry, however.

Q: How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication field? Why or why not?

Anon D: I would at least be interested in investigating the benefit of such an arrangement.

Q: Are there any environmental concerns with microfabrication and if so, what are they and how are they dealt with?

Anon D: The main environmental concerns with microfabrication would be the nasty chemical by products from process technology. Disposal would need to be conducted with the appropriate processing and disposal techniques, so that the waste products do not end up on landfill or introduced into waterways.

Q: What types of government regulations affect your work?

Anon D: I'm fortunately not researching at a level where this affects me, save the desire for more funding.

Q: Are you doing any research in microfabrication? If so, what are the applications of your research?

Anon D: [redacted]

Q: Are you looking to get a job in New Zealand or somewhere else?

Anon D: I'm looking to do research in New Zealand, but that would depend on job opportunities that become available.

Q: If you are looking to get a job in another country, why?

Anon D: Lack of research and development jobs in New Zealand.

Q: If you are looking to get a job in New Zealand, why?

Anon D: To be near family, and a great lifestyle.

Q: What degree(s) are you pursuing?

Anon D: PhD

Q: Do you have any additional comments?

Anon D:

Q: Do you know of other companies or research groups in New Zealand that have interest in microfabrication? Who can we contact and what are your connections with these people?

Anon D:

Interviewee: Anonymous E

Interviewer: Digital

Organization: The MacDiarmid Institute for Advanced Materials and Nanotechnology

Location: Digital

Date and Time: 21/1/2016 10:30:00

Question: What is your name?

Anonymous E: [redacted]

Q: What is the name of your organization?

Anon E: The MacDiarmid Institute for Advanced materials and nanotechnology

Q: Would you like to remain anonymous?

Anon E: Yes

Q: Which part of the microfabrication industry are you personally involved in?

Anon E: Student

Q: What part of the microfabrication industry is your organization involved in?

Anon E: Research

Q: What is your job title?

Anon E: PhD student

Q: What is your job description?

Anon E: PhD student working with experimental spintronics.

Q: What does the word microfabrication mean to you?

Anon E: Making small devices

Q: How does microfabrication play a role in your organization?

Anon E: It is what the entire organization consists of.

Q: How has miniaturization changed technology in New Zealand?

Anon E: Unsure.

Q: What do you imagine microfabrication in New Zealand to be like in 5-10 years?

Anon E: Hopefully more people involved, more companies interested in manufacturing and selling nanotech products.

Q: How do you see ongoing miniaturization affecting the future in 5-10 years?

Anon E: Faster technology, easier storage medias, personal chip implants

Q: How do you think miniaturized technology impacts society in New Zealand?

Anon E: Hopefully to become more technologically friendly. Making everyone more connected to the internet.

Q: What are the strengths of the microfabrication industry in New Zealand?

Anon E: Good basic research.

Q: What are the weaknesses of the microfabrication industry in New Zealand?

Anon E: Almost no industry at all.

Q: How do you feel about collaboration with other organizations?

Anon E: Great!

Q: What do you know about industry clusters and how do you see a cluster operating?

Anon E: Not much.

Q: How aware are you of the microfabrication facilities in New Zealand?

Anon E: Very aware of the academic ones, not very aware of industry ones.

Q: How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication field? Why or why not?

Anon E: Very willing. Sounds like what I do at the moment, plus an opportunity to meet potential employers.

Q: Are there any environmental concerns with microfabrication and if so, what are they and how are they dealt with?

Anon E: Yes. All hazardous waste is sorted and disposed of appropriately.

Q: What types of government regulations affect your work?

Anon E: Health and safety, funding

Q: Are you doing any research in microfabrication? If so, what are the applications of your research?

Anon E: Yes. Magnetic storage media, spin filtering.

Q: Are you looking to get a job in New Zealand or somewhere else?

Anon E: New Zealand for a start and maybe elsewhere later.

Q: If you are looking to get a job in another country, why?

Anon E: Moving closer to family.

Q: If you are looking to get a job in New Zealand, why?

Anon E: Husband is from here.

Q: What degree(s) are you pursuing?

Anon E: PhD-

Q: Do you have any additional comments?

Anon E:

Q: Do you know of other companies or research groups in New Zealand that have interest in microfabrication? Who can we contact and what are your connections with these people?

Anon E:

Interviewee: Anonymous F

Interviewer: Digital

Organization: Spark Transducers

Location: Digital

Date and Time: 28/1/2016 12:12:27

Question: What is your name?

Anonymous F: [redacted]

Q: What is the name of your organization?

Anon F: Spark Transducer

Q: Would you like to remain anonymous?

Anon F: Yes

Q: Which part of the microfabrication industry are you personally involved in?

Anon F: Research

Q: What part of the microfabrication industry is your organization involved in?

Anon F: Manufacturing

Q: What is your job title?

Anon F: Senior Engineer

Q: What is your job description?

Anon F: Develop and refine processes to manufacture ultrasound transducer devices for new products

Q: What does the word microfabrication mean to you?

Anon F: making smaller and more suitable transducers for different purposes

Q: How does microfabrication play a role in your organization?

Anon F: making new transducers rely on microfabrication facilities

Q: How has miniaturization changed technology in New Zealand?

Anon F: the miniaturization has changed our life but not much technology in New Zealand

Q: What do you imagine microfabrication in New Zealand to be like in 5-10 years?

Anon F: there are some universities and industries investing on microfabrication, but not optimistic in 5-10 years as it cost too much money

Q: How do you see ongoing miniaturization affecting the future in 5-10 years?

Anon F: no idea

Q: How do you think miniaturized technology impacts society in New Zealand?

Anon F: Obviously New Zealand is benefited from miniaturization in our daily life

Q: What are the strengths of the microfabrication industry in New Zealand?

Anon F: specific transducer manufacture and prototype of nano fabrication

Q: What are the weaknesses of the microfabrication industry in New Zealand?

Anon F: there are not whole complete IC microfabrication production line in NZ

Q: How do you feel about collaboration with other organizations?

Anon F: it is definitely important to collaborate with other organizations in US, Japan, Europe and China on microfabrication

Q: What do you know about industry clusters and how do you see a cluster operating?

Anon F: Callaghan innovation has sort of spin company like Spark Transducers collaborated with Titanium Solutions to make transducers to industry

Q: How aware are you of the microfabrication facilities in New Zealand?

Anon F: There are some micro/nano fabrication facilities in Canterbury University, Auckland university and Callaghan innovation.

Q: How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication field? Why or why not?

Anon F: No problems. The world is getting small, nobody can survive without other people's connections

Q: Are there any environmental concerns with microfabrication and if so, what are they and how are they dealt with?

Anon F: I think so, as environment is so important to the sustainable development of New Zealand

Q: What types of government regulations affect your work?

Anon F: microfabrication and environment cannot always be double wins

Q: What is your current approach to stay relevant in this rapidly expanding field?

Anon F: to research and develop more different transducers for industry

Q: Is your organization looking to hire more staff?

Anon F: likely to be

Q: What factors make it difficult to compete in a global market?

Anon F: a bit difficult to find more end-users

Q: What are the main and potential applications of your work?

Anon F: ultrasound transducers in medical science, NDT industry

Q: How much money does your organization spend yearly on Research and Development?

Anon F: 100K to 1M

Q: How much money does your organization spend yearly on microfabrication in particular?

Anon F: 100K to 500K

Q: How many people does your organization have on staff?

Anon F: 5-10

Q: How many people does your organization have on staff for microfabrication in particular?

Anon F: 2

Q: Do you have any additional comments?

Anon F: none

Q: Do you know of other companies or research groups in New Zealand that have interest in microfabrication? Who can we contact and what are your connections with these people?

Anon F: You must have now :)

Interviewee: Anonymous G

Interviewer: Rachel Ooyama-Searls

Organization: [redacted]

Location: Auckland

Date and Time: 3/2/2016 13:00:00

Rachel: For our records, could you please state your name?

Anonymous G: [redacted].

R: And the name of your organization?

Anon G: [redacted]

R: Would you like to remain anonymous? We can ask at the end too.

Anon G: Yeah, ask at the end because I (...) say.

R: Which part of the microfabrication industry are you personally involved in? Supplier, manufacturer, researcher, or student?

Anon G: So we'd probably be more on the manufacturer.

R: And then same question, but a little different. What part of the microfabrication industry is your organization involved in? Again, the same four options.

Anon G: All right, so that's me personally, right?

R: The first one was personally.

Anon G: Okay, so personally I'm more of a manager here so I oversee it. Our organization fabricates - so when you say microfabrication, put some boundaries around that. Could you just tell me what scope you believe that you're looking at for this?

R: Anything from the millimeter to micrometer scale. Also, we don't exclude nano. Devices that contain these things, so they can be macro devices but contain the microfabricated parts.

Anon G: Yeah, so some of our instrument that we sell has microfabricated parts in it and as we go into the future, there will probably be more of it.

R: What is your job title?

Anon G: I have probably about three of them, but the most used one is Product Development Manager.

R: In your own words, can you give us your job description?

Anon G: That's difficult. Basically I run the product development at [redacted]. So the Research and Development side of it, as well as look after the production department and support department. But my job is to basically see that the product roadmap of [redacted] is fulfilled and to look out into the future and make sure that we have a full roadmap and that it's achieved.

R: What does the word microfabrication mean to you?

Anon G: That's why I was asking before, because it means different things. To me, microfabrication is often associated with silicon devices or microfluidic devices. I would tend to more generalize today to - additive manufacturing is actually getting into the microfabrication arena as well. Basically another thing that will be on the micrometer scale would become that thing. And there's a lot of different methodologies other than your typical silicon semiconductor one that used to be sort of the - I guess it's the gold standard, but there's other ones competing.

R: How does microfabrication play a role in your organization?

Anon G: Well the heart of our instrument is a nanoport, which has got a tiny hole in it. It's (...) depending on what size it is. We have different sizes, but they can be as small as a micron across or thereabouts. So that is our key fabrication thing, but in the future microfluidics is going to play a big part. So fabricating microfluidic devices, integrated pores will be a key thing in the future.

R: In your opinion, how has miniaturization changed technology in New Zealand?

Anon G: Slowly. I think we've been an end consumer of it rather than a driver of it. So I think it's like everyone in the world has got smaller devices because of the available devices you can get off the shelf. So basically a cost type industry, rather than a necessary producer like ourselves, and I think it's something that needs to change. So having facilities in New Zealand that made it easier access to these sort of things would actually help.

R: What do you imagine microfabrication in New Zealand to be like in the next 5-10 years?

Anon G: I think there will be a lot more stuff done around microfluidics and different ways of achieving microfluidics. And there's also going to be a lot more sort of additive manufacturing capability that's done around the micro scale as well. Possibly using laser based systems, I don't know.

R: How do you see the ongoing miniaturization of technology affecting the future in the next 5-10 years?

Anon G: Okay, in the next 5-10 years it's going to absolutely disrupt pretty much every industry. There will not be an industry that manages to escape the resulting impacts of what's happening today in research labs.

R: And how do you think miniaturized technology impacts society specifically in New Zealand?

Anon G: Specifically related to New Zealand?

R: Yup.

Anon G: I don't think most of our society is aware. But, you know, your cell phone's built basically on microfabrication and there's accelerometers in there. But the Fitbit watches that everyone's using comes about because of microfabrication facilities. The diagnostics that be in the hospitals and all that will be enabled by microfabrication giving new diagnostic capabilities. So society has been hugely impacted by it, but probably most people are not aware.

R: What do you consider the strengths of the microfabrication industry in New Zealand to be?

Anon G: I think there's strong research groups. Auckland and Canterbury University have quite good microfabrication facilities, and I think Otago does as well. But as many are university-based at the moment.

R: And what do you consider the weaknesses of the microfabrication industry to be here in New Zealand?

Anon G: Yeah, it's that they're university-based. There's a teaching/research focus rather than a commercial focus. So for me to access some of it is fine, I can access it through students. But then to actually take that to the next step up, creating a commercial partnership, I have to go through some university to do it. And they're not really geared up for that sort of thing.

R: So you think there's a lack of communication between the two sectors?

Anon G: There's a lack of ability to take it out of the university into commercial production facilities without going overseas usually. If I wanted to make my own customized thing, I could probably find universities that might be able to design it. But if I was going to fabricate it, there's nowhere in New Zealand I can do it. A microfluidic device, if I was to get it designed at a local university, where do I get it commercially fabricated? Overseas, probably.

R: How do you feel about collaboration with other organizations?

Anon G: We collaborate extensively. We probably have three or four collaborations going within New Zealand. I know company-wide, it's something like sixty to eighty. Some of them are more significant than others, but it's a significant part of doing business.

R: What do you know about industry clusters and how do you see a cluster operating?

Anon G: I haven't had too much to do with industry clusters, but my utopian view would be that you'd actually have a bunch of people pool together to get a resource that they couldn't afford on their own. So a shared fabrication facility that they don't have to pay out for themselves, but they sort of get at favorable rates. So if I went to a commercial outlet, it would cost me a fortune because I've got to get a big profit for the shareholders but if I had a cluster then the access and expertise and abilities to integrate would be less of a hurdle to jump over, less of a barrier.

R: How aware are you of the other microfabrication facilities in New Zealand?

Anon G: I know of one, a few of them, but probably not that aware. There must be other ones out there I could utilize that I don't know of. So I know Canterbury's got quite a good setup. I know Auckland University do a lot with laser fabrication, Photon Factory up there. I know Otago

University have done stuff, but I'm not sure what they've got and I wouldn't know too much about (...).

R: How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication field? And why or why not?

Anon G: I'd be extremely willing because we have roadmap needs that involve microfabrication and we need some way to enact them. So if there's a cluster that could actually get us our in means, then I'd be keen on that. Did that get all the questions? There were about three questions in that one, weren't they? I mean, things against joining it would be loss of IPR and ability to sort of get what we need at a reasonable cost. So if there's significant NREs or upfront costs or anything like that then that issue hamstrings things.

R: Switching gears here. Are there any environmental concerns that you know of with microfabrication? And if so, what are they and how are they dealt with?

Anon G: I don't know of any specific environmental concerns. There's, obviously with semiconductor devices or anything like that, there's always your concerns about hazardous chemicals and stuff which you have to be taking into account. But I don't know of any special…

R: Also, what types of government regulations affect your work, if any?

Anon G: You mean New Zealand Government ones? So I mean we're affected by pretty much Health and Safety stuff as well as - that's the main one. There's a whole lot of export-type ones I guess which come into account. There aren't others that affect the business that I know of. Did you have any in mind that you were specifically thinking of?

R: No, just trying to get a feel for it. What are the main applications of the work you do here?

Anon G: Main applications, so you mean of the work or [redacted] in general?

R: [redacted]

Anon G: We're a manufacturer, so we manufacture instrumentation. So the output is a product that we can sell to others.

R: What is your current approach to stay relevant in the rapidly expanding field of microfabrication?

Anon G: So microfabrication is a means to an end for us. So we don't do microfabrication, but we utilize it. So as such, I'm always on the lookout for collaboration, people who actually know what the state of the art is so that we can utilize their expertise, so we don't actually have to reinvent the wheel ourselves. So rather than stay relevant, we want to work with people who are relevant.

R: How much money does your organization spend yearly on Research and Development, if you can tell us?

Anon G: I think it's quite a high percentage of revenue, it's about 33%.

R: Then what percentage would you say, of that, does your organization spend on microfabrication in particular for Research and Development?

Anon G: I don't - I can't say; I'd have to hazard a guess. I don't really know, but it'd probably quite a low percentage because it's done by collaborations, so it'll probably only be a few percent of that.

R: How many people does your organization have on staff?

Anon G: It's about 27.

R: And how many people would you say, if any, are staffed for microfabrication in particular?

Anon G: There's no one specifically tasked with microfabrication, it's not like a - it's a bit like saying someone's in charge of photocopying. People just do it. But there's probably about one FTE of work in microfabrication. Like I said, a lot of that is in terms of working with collaborators to achieve it.

R: Is your company looking to hire more staff?

Anon G: Yes, possibly in microfabrication or microfluidics. But that is dependent on a lot of things.

R: How do international trends shape the future of New Zealand microfabrication or devices with microfabrication in them?

Anon G: Totally, the New Zealand economy is not a - it doesn't support itself. So 90% of what we make, or higher, is exported. For any technology company in New Zealand, that's the same deal. They don't survive off the New Zealand economy. There isn't a New Zealand economy; there's a world economy, and we play in that. So as such, you don't go into business in the technology business in New Zealand thinking you're going to make money out of New Zealanders. You go into business thinking, "I'm going to export." So any international trend is applicable. If the world is going down this path, we better know that we can compete if we're not going down that path. So any trends towards a particular technology have to be taken seriously.

R: And what factors do you think make it difficult to compete in this global market?

Anon G: Well at the moment it's changing very rapidly, so there's a significant amount of startups in the world all trying to take their clever idea to market. Things like Kickstarter are helping that. So it's extremely hard to stay in the market and then innovate it rapidly to keep up. So just a matter of innovation going on around the world is probably a significant factor.

R: We're coming to the end of our interview here. Do you have any additional comments you'd like to add?

Anon G: Not really. I think, I mean, one of the things that is key is being able to access timely, state-of-the-art knowledge for New Zealand industry. We often, a lot of small companies in New Zealand and such, we don't have the budgets of some of the multinationals, so we can't just go and buy a startup that's doing industry and stuff. You've possibly heard of the number 8 wire thing. A lot of people in New Zealand talk about that proudly. I don't, because number 8 wire is an improvisation, it's not an innovation. You use number 8 wire to get around not having the right thing. So in terms of microfabrication, we need to get rid of the number 8 philosophy and actually embrace - and this is where a microfabrication facility would come in. We wouldn't need the number 8 wire; we wouldn't have to improvise because we've got the thing we need. And so I'm quite interested to know how feasible it would be to have a cluster in New Zealand and what that cluster would look like.