Ministry of Business, Innovation & Employment

National Science Challenges

Potential Challenges for Consideration by Peak Panel

Manufacturing and Other Non-primary Sector Economic Activities

February 2013

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1 Introduction

The potential challenges in this area cover a wide range of issues related to manufacturing and other non-primary sector economic activities.

Twenty five submissions were received from the science sector in this domain. These submissions have been grouped as shown in Table 1.

Table 1: Summary of proposed challenges by grouping

Entry Id	Challenge
Increasing exports and export value	
139	Utilize Seaweed, an undervalued resource
249	Extracting value from New Zealand's Seaweed resources
271	To develop new medicines from organisms living in New Zealand nature
428	High value manufacturing/ Innovative technologies
Developing advanced materials infrastructure to make high value products	
52	Develop engineered materials with improved performance, properties or environmental impact for use in the manufacture of New Zealand products. Just as glass and then carbon composites boosted the marine industry, new materials can boost exports.
112	Develop new advanced material processing methods based on new micro design structures.
133	Develop and then construct a new material based technology and then transfer the skills and knowledge to a manufacturing base to support commercialisation activities.
331	New Zealand's material difference : Materials science for the benefit of New Zealand
417	To increase the wealth of New Zealand by significantly increasing the export returns of smart high value innovative technologies
446	Delivering a step change in high value added exports
456	Developing new manufacturing and materials capabilities so that by 2030, 20% of our exports will comprise advanced materials and creative high-value, high-technology products and processes, based on New Zealand's innovative intellectual capacity
474	High Tech "New Zealand Inc." Creating an agile, high-value, high wage economy
Increasing productivity	
68	Scalable cognitive systems for high value knowledge extraction using cloud technologies
91	Advancing mechanisation and automation of New Zealand's agricultural and horticultural sectors to overcome constraints in intensification and expansion induced

Entry Id	Challenge
	by decreasing supply of skilled and unskilled labour
261	Productive plants for a profitable and sustainable New Zealand. Plants are essential for human life and contribute to 70% of New Zealand exports. We need smart, flexible and profitable primary production in a changing world to feed an increasing population sustainably."
316	To capture a proportion of the 1.6 million bobby calves slaughtered within their first two weeks of life and rear for beef production. If 50% could be reared this has potential to add $1 billion in farm gate returns to New Zealand agriculture
Minerals	
88	To generate wealth from petroleum resources in the exclusive economic zone
147	To explore the geology and geophysics of our offshore basins so we improve our knowledge of their resource potential and their tectonic history
247	Establishing a research and development project that explores the potential of South Island Silica deposits
307	Wealth and Security from Geological Resources
328	Turbocharging New Zealand's economic growth and future-proofing our economic resilience and global competitiveness by bringing forward the managed exploration and development of oil and gas resources within our vast Exclusive Economic Zone
335	The Challenge is that New Zealand's past economic performance has been poor. The goal of this challenge is to develop larger and more diversified export income sources to make the New Zealand economy more resilient and prosperous
378	Environmentally-responsible intensification of land and water-use, in relation to New Zealand primary industries , to benefit the economy and society
379	Environmentally-responsible identification of and development of resources within New Zealand's largely-undeveloped marine jurisdiction, to benefit the New Zealand economy and society, consistent with the UN Convention on the Law of the Sea 1982
409	Accelerate development and extraction of wealth from New Zealand's marine resources, while maintaining the diverse range of ecosystem services that our vast oceanic region provides

2 Increasing exports and export value

The submissions in this group are shown with their underpinning themes in the table below. Each submission follows in full.

Table 2: Summary of proposed challenges and themes

Entry Id	Challenge	Themes
139	Utilize Seaweed, an undervalued resource	1. Identify and characterize the resource 2. To determine new uses for seaweeds and their extractives 3. To grow seaweed to produce fuel and reduce pollution
249	Extracting value from New Zealand's Seaweed resources	1. Understanding the seaweed resource 2. Adding value to seaweeds 3. Delivering a sustainable global future
271	To develop new medicines from organisms living in New Zealand nature	1. To expand and mine Landcare Research's digital species catalogue for species that could potentially generate biologically active substances. Extract and isolate, purify, and characterise substances and deposit these in a substance repository 2. To test substances for biological activity or interaction with potential biological targets. To identify hits and optimise these by synthetic chemistry approaches into lead biological actives. In addition, to identify potential new biological targets 3. To develop a viable vehicle and infrastructure to commercialise validated active compounds in New Zealand. Application of new business and management models to encourage investment and support research as well as to deliver on-going economic benefit to New Zealand
428	High value manufacturing/ Innovative technologies	1. To develop a sustained pipeline of world class people and IP that can underpin a high tech emerging technologies sector in New Zealand 2. To achieve rapid exchange of knowledge and technology between research providers and industry 3. Growing, at all levels, the pipeline of STEM-based (Science, technology, engineering, mathematics) capability that is critical to New Zealand's future ability to innovate 4. Turning New Zealand's geographical isolation and time zone difference into a competitive advantage by providing 'downtime' services to companies across the globe

Entry ID	139
Utilize Seaweed, an undervalued resource	
Summary	This challenge proposes to perform research to characterise hundreds of species of seaweed, the potentially useful biomaterials they make, and how to viably harvest these materials on commercially beneficial scales
Theme 1 **Identify and characterize the resource**	
Importance to New Zealand	New Zealand has a large coastline, and over eight hundred species of seaweeds, many of them unique to New Zealand and many of them with unknown properties. We have opportunities that would have great economic benefit if we could produce greater amounts of selected species. We need to determine what we have and how much we could produce to support the other themes below, and move from the hunter-gatherer to the farmer As an example, this laboratory developed a new gel (Nemidon) that is being marketed as a specialist skin moisturizer for medical purposes. If orders of magnitude more of the basic seaweed could be produced this could produce a basic cosmetic moisturizer, a market of at least $15 billion
Research components	(a) Mapping the occurrence of major beds of algae on our coastline, determine the limiting conditions for their growth, and determine how to cultivate them sustainably and without general damage to the overall ecosystem (b) Characterizing the occurrence of predominant algae, and determining what materials or chemicals they could produce (c) Determining how to harvest from the seabed and from beach cast with minimal other environmental effects (d) Determine how to produce and harvest desirable seaweed through aquaculture. This would include the growing of seaweed in the presence of other aquaculture, e.g. mussel farming, where seaweed could absorb excess nitrogen and phosphate that would otherwise pollute the water
Theme 2 **To determine new uses for seaweeds and their extractives**	
Importance to New Zealand	Something in the order of a billion dollars per annum of algal polysaccharides are sold, while commercialization in New Zealand is restricted a few cottage-sized industries, together with an agar extraction industry, which started during world war two as a response to the absence of Japanese supply. This laboratory has identified at least five new products that should have significant commercial value and several more with strong beneficial medical responses in certain tests. Significantly more research is required to verify responses/safety. The chemical modification of existing extractives has also led to products that give significant responses in certain screening tests
Research components	(a) Determine which seaweeds are useful for pollution remediation, and whether

	they can be used at the same time for commercial benefit. (b) Develop new uses for existing materials and the development of new products. (c) Examine medical applications determine the nature of the action and carry out trials. As an example, one such product has already been shown to alleviate eczema in over 90% of cases better than any other product (according to users) but somewhere between 5-8% of users get a violent enhancement. If we could understand this better, there would be potential for considerable economic benefit
Theme 3 **To grow seaweed to produce fuel and reduce pollution**	
Importance to New Zealand	Most people are aware that oil is not an unlimited resource. The marine environment is one of the few places where large-scale cultivation of plant material is at least theoretically possible. This laboratory has already shown that microalgae can produce useful yields of fuels and chemicals through hydrothermal treatment, but microalgae are not the easiest to harvest. Seaweed has also been converted hydrothermally to oxygenated hydrocarbons that should be able to be converted to petrol/diesel. Alternatively, seaweeds could be recycled into the soil as fertilizer, or carbonized to fix carbon. This theme would capitalize on New Zealand scientific capability already in existence, but which would also buy us into international cooperative programs
Research components	(a) Determine which macro algae respond best to hydrothermal treatment, and determine which conditions produce the highest yields of products. (b) Determine which routes are the most likely to yield the lowest cost products (c) Determine whether these products/yields are adversely affected by growing seaweeds in nutrient-rich water

Entry ID	**249**
Extracting value from New Zealand's Seaweed resources	
Summary	This challenge proposes to perform research to characterise and quantify the hundreds of species of seaweed which surround the New Zealand coastline. This will result in the identification of seaweed species that produce potentially commercially valuable products. Research will be carried out to characterise the ecological role that these target species fulfil, with the aim of devising sustainable harvesting practices (such as developing novel technologies to assist in large-scale seaweed farming practices).
Theme 1 **Understanding the seaweed resource**	
Importance to New Zealand	New Zealand's coastline boasts over eight hundred species of seaweeds, many of them unique to New Zealand. For centuries seaweeds have been collected from

	our coastline for a range of purposes. Several species such as karengo (as food) and rimurimu (used as storage bags - pohatiti) are taonga; others have been collected as fertiliser and harvested for extraction of gelling agents such as agar. In recent years researchers have looked more closely at New Zealand's seaweed resource and extracted many useful compounds, including antibiotics, anti-viral compounds and gels that help to heal burns. The range of potential uses for our native seaweeds continues to grow as more species are investigated and new compounds discovered. The versatility of seaweeds is reflected in their broad ecological role. In nature seaweeds form the basis of our coastal ecosystems providing shelter and food for a range of animals, and acting as a nursery for our most valuable fisheries. The ecological importance of seaweeds has led to reluctance to allow their commercial exploitation, and harvest of the most valuable species is restricted to collection of beach cast material in a limited number of areas. Prohibition on harvest has limited the potential for the industry to develop and to exploit the new opportunities for seaweed products. However, before we seek to exploit our seaweed resource we must first seek to understand it, learn how to care for it and learn how to move from hunter-gatherer to farmer.
Research components	The theme has 4 key research components: 1. Quantifying the seaweed resource: Despite the abundance of seaweeds we still have little knowledge about the size of the resource, its regeneration rates or its regional diversity. Understanding these factors is critical to understanding the potential resource surrounding our shores. 2. Identifying the ecosystem functions of target species: While it is recognised that coastal seaweed beds are home to a range of species their ecosystem functions in terms of acting as nursery's, cleaning our oceans, and protecting shorelines require further study before sustainable seaweed harvesting plans can be established. 3. Developing Sustainable harvest strategies: New Zealand can boast some the world's most sustainable fishing strategies, however harvesting strategies for fish will not work for seaweeds. To ensure sustainability of the seaweed resource and the ecosystem it supports the robustness of seaweed beds to harvest on a range of scales and frequencies must be defined before beds can be commercially exploited. 4. Developing seaweed farming technology: Ultimately the most efficient way to produce our most valuable seaweeds will be by learning to farm them. Experience overseas shows that seaweeds have complex lifecycles and specific environmental requirements. However, once appropriate culture techniques have been defined seaweed farms have been shown as being environmentally beneficial as well as profitable ventures.
Theme 2 **Adding value to seaweeds**	
Importance	Commercial uses for seaweeds as commodities are well established. Seaweeds

to New Zealand	are consumed in many countries and they have been recognised as forming a core ingredient of a healthy diet. However, most seaweed consumption is indirect, with over $1 billion of seaweed derived food binders are traded internationally each year. Despite our extensive coastline New Zealand cannot compete for commodity production against nations that have low labour costs and poor environmental performance. Taking the lead from our land based primary industries, it is important that in New Zealand we seek to find and extract the highest value products from our seaweeds to supply to niche markets that value quality over quantity. Researchers have already identified compounds from New Zealand seaweed with unique gelling agents that are of significant value to chemical industries and antiviral and antibiotic properties sought after by medical science. Many valuable compounds are waiting to be discovered. However it is a long way from identifying chemicals to developing new products, and a significant research support will be required to ensure the value compounds from our seaweeds are not left sitting on the laboratory shelf.
Research components	This theme has 3 research components: 1. Seaweeds for human consumption. Studies overseas have linked seaweed consumption with health benefits such as reduced incidence of cancer, reduction in diabetes and reduced cardiovascular disease. Seaweed consumption in New Zealand is very low but the potential to include whole seaweed products into healthy and tasty and affordable foods offers a real opportunity to directly address some of new Zealand's most pressing health concerns. 2. Developing new compounds: Screening all of New Zealand's seaweed resource for valuable compounds is an expensive and high risk development strategy. However, sufficient groundwork has been done in New Zealand and overseas to enable a much focussed approach to be taken to screen certain species groups for specific biologically active compounds, reducing risk and increasing chances of a breakthrough. 3. Developing new seaweed based products: Commercialising compounds that have shown biological activity or unique chemical properties is time consuming and expensive, and consequently many potentially high value compounds remain on our laboratory shelves. Establishing a development pathway with staged funding opportunities will enable the most beneficial and valuable of these compounds to be developed into marketable products that will support seaweed producers and deliver new revenue streams to New Zealand chemical manufacturers.
Theme 3 **Delivering a sustainable global future**	
Importance to New Zealand	In nature seaweeds perform a range of valuable global functions. They trap greenhouse gases and help to offset the acidification of our oceans and mop up pollutants that wash into coast from our cities and farms. Because seaweeds absorb nutrients over time, analysis of the composition of these seaweeds can often indicate the source of pollutants more accurately than water samples, and

	allow more effective controls to be established. In Asia, Canada and Europe large scale cultivation of seaweeds is increasingly seen as a way of offsetting the nutrient enrichment of coastal ecosystems from agricultural run-off and finfish culture. The development of integrated aquaculture systems that use seaweeds to remove nitrogen waste from salmon farms has gained favour in Canada where eutrophication of bays from salmon farm wastes was a major concern to environmentalists. In the most polluted areas, seaweed biomass is not suited for human consumption and is often used as fertiliser for terrestrial crops, reducing the need for chemical fertilisers and adding valuable micronutrients to the soils. However as the search for renewable energy sources continue to gain momentum, there is increasing interest in the use of seaweeds as biofuels. The biofuel potential of their single celled cousins, known as microalgae or phytoplankton, has already been demonstrated. Our large brown seaweeds (known as macro algae) provide a much more convenient way to produce the biomass required for biofuel development, but work remains to be done to develop the technology to turn seaweeds into bio-diesel.
Research components	The theme has 4 research components: 1. Pollution Monitors: Developing seaweed based pollution monitoring tools that act as low cost systems for detecting pollution in our marine environment. 2. Integrated Multi-Trophic Aquaculture: Testing and verifying the potential for commercially useful species of seaweeds cultured in close proximity to finfish farms to remediate wastes in the marine environment. 3. Biofuel Production: Developing the technology to efficiently convert seaweed biomass (produced to remediate other environmental impacts) into biofuels. 4. Environmentally Defined Properties: Many of the key chemical attributes of seaweed reflect the environment that the plant is grown in. The potential to use seaweed crops for specific purposes (food, chemicals, biofuels) may therefore be influenced by determining the effects of environmental quality. Identifying these linkages will be crucial to establishing the direction that the New Zealand seaweed industry will take in the longer term.

Entry ID	**271**
To develop new medicines from organisms living in New Zealand nature	
Summary	The goal is to develop new medicines using Landcare's digital species catalogue with a research programme using the following themes: (a) expand and mine catalogue for species that could potentially generate biologically active substances (b) test substances for biological activity or interaction with potential biological targets and (c) develop a viable vehicle and infrastructure to commercialise validated active compounds in New Zealand.

Theme 1 **To expand and mine Landcare Research's digital species catalogue for species that could potentially generate biologically active substances. Extract and isolate, purify, and characterise substances and deposit these in a substance repository**	
Importance to New Zealand	Some of the most selective and potent biologically active substances are found in nature. Many species found in New Zealand are unique and they may be a rich and unique source of biologically active substances that could be used or developed in many different areas, e.g. pest control, veterinary, food industry, pharmaceutics, etc. It is therefore important to explore and establish the potential value of New Zealand's vast natural resources in this context and protect it.
Research components	Many specialist field biologists (incl. marine biologists) are required to collect and document specimens. Special chemical extraction procedures are required to isolate and characterise the pure substances. Maintenance of the substance repository and quality control (i.e. curation) are essential for any bank, be it a data- or tissue-bank. All these things have to be done on large scale, i.e. in large numbers, and in a semi-automated way. This may require the development of new methodologies and/or technologies for extraction and purification and storage of substances from natural specimens, for example.

Theme 2 **To test substances for biological activity or interaction with potential biological targets. To identify hits and optimise these by synthetic chemistry approaches into lead biological actives. In addition, to identify potential new biological targets**	
Importance to New Zealand	Many biological active substances found in nature cannot be directly utilised. Biological activity and target need to be established and activity needs to be further optimised through synthetic analogue development. This requires full chemical identification of the substance. Lead candidate analogues will require a data package that takes them to a commercial gateway and enables any regulatory filing that may be required. Therapeutic benefit must be established in clinical trials. Newly discovered compounds or even classes of compounds may have biological targets that not yet been identified as such. Arguably the pharmaceutical industry world-wide is looking for new drug targets. For example, the war against cancer is far from won.
Research components	Large-scale biological screening is required in non-cell- and cell-based models to find natural substances with biological activity. These hits need to be chemically identified to allow analogue development and lead optimisation by (medicinal) chemists. Further biological testing in advanced models is the next step followed by pharmacological and toxicological testing in pre-clinical animal models. Formulation scientists can develop and apply sophisticated ways of formulating the new chemical entities and optimise drug stability. New biological targets will be identified in genomic and proteomic screening and protein targets and target interaction will be studied by protein scientists and crystallographers and computer modelling. Clinical trials need to be conducted by dedicated trial units

	and in close collaboration with the researchers.
Theme 3 **To develop a viable vehicle and infrastructure to commercialise validated active compounds in New Zealand. Application of new business and management models to encourage investment and support research as well as to deliver on-going economic benefit to New Zealand**	
Importance to New Zealand	The development of new medicines and therapeutics requires huge investments in time and money. If New Zealand's natural resources were to be exploited for medical benefits it would make sense if: a) New Zealand would retain some ownership; b) New Zealand in particular would receive monetary benefit (ROI); c) New Zealand patients in particular would benefit; d) New Zealand would build and maintain the necessary infrastructure to avoid 'one-off's'. Big pharma overseas are moving towards new models to partner with academia and small biotech's (e.g. shared-risk models). New Zealand Inc. must develop new ways of commercialising research that maximises d.) return to the country and not just in the short but also medium and long term. Lastly, the substance repository could be made conditionally available for commercial gain.
Research components	In order to fund the discovery and drug development stages it is imperative to attract commercial interest. New paradigms of commercialisation of research, science & technology need to be developed with and by business-focussed specialists. Strictly speaking, this is not science but it does involve people with highly specialised skills and knowledge who ideally also have a good grasp of biomedical research.

Entry ID	**428**
High value manufacturing / innovative technologies	
Summary	The goal of this proposal is to establish a nimble and entrepreneurial 'innovation ecosystem' in which innovation and innovators are highly mobile between research organisations and the private sector so that New Zealand can diversify its export base from a disproportionate reliance on primary products.
Theme 1 **To develop a sustained pipeline of world class people and IP that can underpin a high tech emerging technologies sector in New Zealand**	
Research components	Supporting ambitious, high-quality fundamental research that aims to become world first at developing and proving new technologies or insights, in an environment that closely links with end-users both nationally and internationally. This could include, but should not be limited to: pico-tech engineering, quantum communication, information processing and communication, medical devices,

	diagnostics, new materials, and agritech.
Theme 2 **To achieve rapid exchange of knowledge and technology between research providers and industry**	
Research components	This theme would consist of two key components: • Developing an innovation system based on highly mobile people — Encouraging and supporting highly trained postgraduate students and staff to transfer the knowledge to industries &/or embark on their own enterprise development. • Developing an accessible innovation system — Making University, CRI and Polytechnic scientific and engineering related equipment more readily available to industry and other research teams to help create porous boundaries between academia and industry, and aid the transition of businesses from not investing in R&D to one of beginning to do so.
Theme 3 **Growing, at all levels, the pipeline of STEM-based (Science, technology, engineering, mathematics) capability that is critical to New Zealand's future ability to innovate.**	
Importance to New Zealand	This theme is critical to building a STEM-literate and STEM-appreciative population. This is key, not only for developing a greater quantity and quality of STEM practitioners for research providers and industry alike, but also the more broad-based recognition of the importance of these disciplines in society that will flow down into primary and secondary education decision making.
Theme 4 **Turning New Zealand's geographical isolation and time zone difference into a competitive advantage by providing 'downtime' services to companies across the globe**	
Importance to New Zealand	New Zealand is ideally placed to provide high-end expertise in areas such as design innovation and ICT to global corporate design processes in order to offer them 16 or possibly 24 hours per day skilled workforce.
Research components	The Science Challenge is to learn from and expand existing design collaboration models (e.g. Airbus consortium) to fit New Zealand within a global context. It will also require determining the modes of communications (software/hardware and human factors) that will optimise collaboration between remotely located teams.

3 Developing advanced materials infrastructure to make high value products

The submissions in this group are shown with their underpinning themes in the table below. Each submission follows in full.

Table 3: Summary of proposed challenges and themes

Entry Id	Challenge	Themes
52	Develop engineered materials with improved performance, properties or environmental impact for use in the manufacture of New Zealand products. Just as glass and then carbon composites boosted the marine industry, new materials can boost exports.	1. Develop bio-sourced composites for structural applications. New Zealand has significant resources available for the manufacture of bio-sourced structural materials but these provide poor mechanical properties. Improvements will allow new uses such as car chassis 2. Failure analysis capability. In developing new material there is a need to understand failures, such that improvements can be made. New Zealand has organisations capable of analysing failures of metals but there is little capacity for composite materials 3. Multi-scale modelling 4. Development of powder titanium
68	Scalable cognitive systems for high value knowledge extraction using cloud technologies	1. Scalable learning algorithms. Combine existing machine learning techniques with cloud technologies to allow automatic scaling of computational learning. Flexible resources based on the demands of incoming data need to be developed. 2. Ethics, tolerance and safety of on-line and shared data and the new breed of AI algorithms that will manipulate user's data autonomously 3. Robotics and embodiment of intelligence. Cognitive systems face the challenge of learning information that is grounded in real-world experiences.
112	Develop new advanced material processing methods based on new micro design structures	Withheld by request of submitter due to commercial sensitivity.
133	The goal is to develop and then construct a new material based technology and then transfer the skills and knowledge to a manufacturing base to support commercialisation activities.	1. The goal of this theme is to create new technology and to transfer the this to a manufacturing base to create high skilled jobs for generations of Kiwis
331	New Zealand's material difference : Materials science	1. New and improved materials from New Zealand's natural resources

Entry Id	Challenge	Themes
	for the benefit of New Zealand	2. Materials applications within the New Zealand environment 3. Novel materials for the global market-place
417	To increase the wealth of New Zealand by significantly increasing the export returns of smart high value innovative technologies.	1. Develop advanced technologies to boost manufacturing productivity and competitiveness utilising digital and information sciences, physics and biotechnology 2. To develop innovative and eco-efficient technologies for the production of advanced materials for industry and consumers 3. Improve the management of data in business using innovative digital technologies, smart information systems and complex system models for manufacturing 4. To significantly increase cross-sector collaboration and innovation, including consumer-driven design processes and commercialisation
446	Delivering a step change in high value added exports	1. Unleashing the new bio-economy - New high valued bio-products 2. New Zealand relevant production systems - Processing and supply systems 3. Expert systems 4. Global connectivity - Partnerships for value
456	Developing New Manufacturing and Materials Capabilities - Developing new manufacturing and materials capabilities so that by 2030, 20% of our exports will comprise advanced materials and creative high-value, high-technology products and processes, based on New Zealand's innovative intellectual capacity	1. Novel Agri-Technologies: To create an export economy based on unique New Zealand products, process and product solutions in agri-technology, including forestry and fishing 2. To develop intellectual capital to create high-value biomaterials derived from New Zealand's natural resources or from innovative synthetic pathways 3. To develop a thriving New Zealand export economy based on software, communications hardware and health, education, emergency services and security information technologies 4. By 2030, 20% of New Zealand exports will be based on products that leverage export manufacturing benefit from niche areas of expertise, such as fisheries, adventure tourism, health tourism, film industry, marine craft, and rugby
474	High Tech "New Zealand Inc." Creating an agile, high-value, high wage economy	1. Achieving scale in novel digital technology-based businesses through collaboration 2. Creating a high value/innovation workforce and understanding of emerging economic opportunities based on novel technologies 3. Accelerating growth of niche high tech/high value manufacturing clusters including medical

Entry Id	Challenge	Themes
		devices and technologies, novel materials, niche manufacturing and agritech 4. Establishing a pharmaceutical industry in New Zealand by 2020 that utilises New Zealand's medical biotechnology experience and expertise to develop new therapeutics

Entry ID	52
Develop engineered materials with improved performance, properties or environmental impact for use in the manufacture of New Zealand products. Just as glass and then carbon composites boosted the marine industry, new materials can boost exports	
Summary	The goal is to develop engineered products with improved performance/outcomes that can be used in the manufacture of New Zealand products. The proposed research programmes includes: **(1) The development of bio-sourced composites for structural applications** (there is a need to improve the mechanical properties of bio-sourced composite materials. improve durability (i.e. longevity) of bio-sourced materials and disposal etc. **(2) Failure analysis capability** (need to understand failures, develop non-destructive inspection and forensic analysis capabilities for composite materials) **(3) Multi-scale modelling - m**ulti-scale modelling will enable material defects to be considered when modelling and analysing structures for design adequacy **(4) Development of powder titanium -** to substantiate the mechanical properties for use in structural applications.
Theme 1 **Develop bio-sourced composites for structural applications. New Zealand has significant resources available for the manufacture of bio-sourced structural materials but these provide poor mechanical properties. Improvements will allow new uses such as car chassis**	
Importance to New Zealand	Development of bio-sourced materials for use in structural applications such as cars, buildings, machinery, sports equipment, etc will provide an export industry and hence revenue stream. Not only may the raw material (e.g. wood) be exported but higher value manufactured materials or indeed, manufactured products, may be exported, generating jobs in New Zealand.
Research components	Primarily, there is a need to improve the mechanical properties of bio-sourced composite materials. While they may currently be suitable for low cost non-structural applications (packaging, etc), improvements are required to challenge conventional composites or metals in structural applications. Other aspects such as durability (i.e. longevity) of bio-sourced materials and disposal will require

	consideration.
Theme 2 **Failure analysis capability. In developing new material there is a need to understand failures, such that improvements can be made. New Zealand has organisations capable of analysing failures of metals but there is little capacity for composite materials**	
Importance to New Zealand	Forensic analysis of composite materials is crucial to understanding structural failures and hence preventing their recurrence. Capabilities do exist for such analysis of metal structures but only the Defence Technology Agency (DTA) is working to develop this capability for composites. Further effort is required in academia and industry.
Research components	Development of non-destructive inspection and forensic analysis capabilities for composite materials. It should be noted that these capabilities are not only required to provide credibility to New Zealand produced composite materials and structures but also for the investigation of in-service failures of equipment, vessels and aircraft.
Theme 3 **Multi-scale modelling**	
Importance to New Zealand	Multi-scale modelling allows the performance of engineered structures to be predicted based on the behaviour of the constituent materials. Development of this capability thus has the potential to greatly reduce the need for full scale testing of structures - saving industry money - while at the same time providing greater credibility of manufactured products and high value jobs for New Zealanders.
Research components	Computational analysis currently has very limited ability to consider the effect of material defects on the performance of a structure. Consequently, there is great reliance on full scale testing of structures with known defects. A recent example I observed was fatigue testing of aged power poles. Multi-scale modelling will enable material defects to be considered when modelling and analysing structures for design adequacy.
Theme 4 **Development of powder titanium**	
Importance to New Zealand	Composite materials are unable to be used against many metals due to the inherent tendency for the metal to corrode, however titanium is an exception. Work is underway in New Zealand to develop low cost powder titanium for use in component manufacture. Use of this material with bio-sourced composite materials in structural applications would be an ideal opportunity to further two complimentary New Zealand products in structural applications.
Research components	My understanding is that powder titanium manufacture is viable and is giving reasonably good material properties. Further work is however required to substantiate the mechanical properties for use in structural applications. Issues such as durability and fatigue need to be considered. Likewise, variations to the manufacturing process may enable greater properties to be released.

Research Gaps and Opportunities	I would comment that there is currently a gap between the users of materials and the materials community. Materials such as bio-sourced composites, nano enhanced materials and coatings, non-destructive inspection and failure analysis and modelling have much to offer manufacturers which would enhance productivity. Closer linking of manufacturers/users is required.

Entry ID	**112**
Develop new advanced material processing methods based on new micro design structures.	
Withheld by request of submitter due to commercial sensitivity..	

Entry ID	**133**
The goal is to develop and then construct a new material based technology and then transfer the skills and knowledge to a manufacturing base to support commercialisation activities	
Summary	The goal of this theme is to create new technology and to transfer this to a manufacturing base to create high skilled jobs for generations of Kiwis. It will require a multi-disciplinary team of scientists working in collaboration for the purpose of constructing a micro structured circuit imbedded in a siloxane polymer mould using nano technological processes. A team of electronic engineers will be required to build the electronic command and control hardware and software technicians to program the hardware for applications in drone technology. Simulation & modelling of the design concepts will be necessary to clearly inform investors and future customers of the capabilities and applications of this technology. The skills and knowledge developed from this research project will be transferred to a manufacturing base to mass produce a range of advanced material based products targeting a global market.
Theme 1 **The goal of this theme is to create new technology and to transfer the this to a manufacturing base to create high skilled jobs for generations of Kiwis**	
Importance to New Zealand	The benefits from a successful outcome of the project to New Zealand will mean an increase in high skilled jobs as this technology will require a scientifically literate work force capable of comprehending scientific concepts. The development of an intensive scientific education program and matching university courses will be necessary for future generations of Kiwis to find work in the manufacturing and other service industries that will grow from this scientific project.

	The development of the new propulsion technology will increase cargo export and import rates per annum and decrease dependence on oil based propulsion systems, in the long term it will increase tourism via new and improve aviation vehicles, create new business services, equip New Zealand defence force with new and advanced capabilities, increase scientific marine research exploration. The benefits from the renewable power generation technology will create a clean source of power that is ready accessible to all New Zealand citizens, reduce pollution and dependence on oil based products, the combination of these two of four applications will revolutionise the way New Zealanders conduct their lives.
Research components	It will require a multi-disciplinary team of scientists from IRL and the Mac Diarmid institute working in collaboration for the purpose of constructing a micro structured circuit imbedded in a siloxane polymer mould using nano technological processes. A team of electronic engineers will be required to build the electronic command and control hardware and software technicians to program the hardware for applications in drone technology. Simulation & modelling of the design concepts will be necessary to clearly inform investors and future customers of the capabilities and applications of this technology. The skills and knowledge developed from this research project will be transferred to a manufacturing base to mass produce a range of advanced material based products targeting a global market.
Research Gaps and Opportunities	In terms of research gaps, I would say, would be in the field of hydro and aerodynamic simulation and modelling, technical engineering to modify the scientific tools and machinery required to conduct the project, training of manufacturing staff in the new material processing methods developed from the project. Detailed skills in creative engineering design methods, multi-dimensional thinking to allow researchers to look at a problem from more than one view point or conceptualization. A detailed understanding of the symmetry of mass at the quantum level and how these dimensions effect the properties of the periodic elements at the atomic and subatomic level, how this relates to E=MC2 and Einstein's theory of Relativity, and why Newton’s laws of Gravity when measured using modern calculations is incorrect. I will know more as I learn the full extent of capabilities that New Zealand’s research centres have.
Comments	Concurrently a corporate governance structure will need to be established to commercialise the technology and operate the manufacturing business to export to global markets initially in two main industry sectors, UAV, UUV drones and Renewable Power Generation systems.

Entry ID	331
New Zealand's material difference : Materials science for the benefit of New Zealand	
Summary	The goal of this proposal is to enable greater economic benefit to New Zealand by from our unconventional natural resources and find material solutions to New Zealand issues. The research programme includes the following themes: (1) **New and improved materials from New Zealand's natural resources** (development of new technologies to produce new engineering materials from New Zealand's lignite resource, to produce engineering Biomaterials from New Zealand's biological resource base, to produce new low technologies (with low capital requirements), to produce engineering materials from New Zealand's mineral resources **(2) Materials applications within the New Zealand environment** - construction of materials for the New Zealand environment, the geothermal environment, the marine environment (corrosion resistant metals etc.), for industrial processes in New Zealand, low-volume materials recycling in New Zealand etc. **(3) Novel materials for the global market-place -** develop a broad church of novel materials from physics and chemistry research
Theme 1 **New and improved materials from New Zealand's natural resources**	
Importance to New Zealand	Every manufactured item in the modern world is built using engineering materials derived from natural resources. New Zealand is blessed with a number of under-utilised forms of natural resource including lignite hydrocarbons; ligno-cellulose biomass and non-conventional metal ores (titano-magnetite ironsand, ilmenite etc., sub-sea sulphides). In a number of cases new scientific R&D endeavour is required to develop industrially-relevant and economically-viable methods of resource transformation (or refining). This theme seeks to develop the science and technology necessary to enable greater economic benefit to New Zealand from our unconventional natural resources.
Research components	Lignite conversion: Development of new technologies to produce new engineering materials from New Zealand's lignite resource (including ethylene-based polymers, resins, carbon fibres and activated carbons). Biomass conversion: Development of new technologies for the production of engineering Biomaterials from New Zealand's biological resource base (including wood products, bio-polymers and bio-composites). New low technologies (with low capital requirements) to produce engineering materials from New Zealand's mineral resources (including low cost refining of titano-magnetite iron-sand, clay ceramics, concrete, glass, etc.)

Theme 2 Materials applications within the New Zealand environment	
Importance to New Zealand	New Zealand is a unique environment in which to work and live. Environmental conditions such as geothermal corrosion and seismicity can lead to engineering materials experiencing conditions well outside normal operation anywhere else in the world. This theme seeks to develop materials solutions to New Zealand specific problems.
Research components	Construction materials for the New Zealand environment (e.g. long-life, low-cost, earthquake- proof, abundant) materials. Materials for the geothermal environment (eg. Geothermal linings and drill-bits, earthquake remediation materials, corrosion proof metals etc.). Materials for the marine environment (corrosion resistant metals, long-life low-cost composites) Materials for industrial processes in New Zealand (e.g. refractory materials for high temperature processes, cutting blades for the wood industry, and stainless steel alternatives for the dairy industry) low-volume materials recycling in New Zealand: New Zealand imports significant quantities of refined metals and other high-value materials which are incorporated within manufactured goods. New recycling technologies are required to enable economic utilisation of many of these materials at end-of-life for the constituent goods. Example materials might include indium-tin-oxide (flat-screens), stainless steel upgrading, lithium (batteries) etc.
Theme 3 Novel materials for the global market-place	
Importance to New Zealand	New Zealand is a small and isolated trading nation. Its economic survival is predicated on the strength of its export revenue exceeding its import costs. A key strategic plank in New Zealand's future economic development is the Development and export of new materials which address commercial opportunities on the global stage.
Research components	This theme will likely cover a broad church of novel materials physics and chemistry research including: Nanomaterial's, Advanced composites, Electronic materials, Advanced Textiles and other advanced materials.
Research Gaps and Opportunities	Theme 1: Biomaterials - Scion has extensive work around advanced wood products and biopolymers. However the biopolymer work underway does not utilise material derived from pinus radiata or other ubiquitous New Zealand biomass resources. Ironsand refining: Despite extensive earlier work by DSIR in the past, I am not aware of any research into novel methods of refining New Zealand iron-sand in the last 20 years. It is overdue re-examination in the light of modern processing technologies and equipment. The most likely partner organisations for this work would be IRL/UoA/University of Waikato + New Zealand steel + Pacific Steel. Lignite conversion: Solid Energy controls nearly all New Zealand's vast lignite reserve. Their market activity has focussed solely on the fuel uses of this material. However several polymers from

	coal plants have now been demonstrated in China, and the economic realities of spiralling crude oil prices means this issue should now assume high priority for New Zealand. Partners might include IRL (Callaghan innovation)/CRL/Canterbury University and Solid Energy + Marsden point refinery. Theme 2: Materials research for the geothermal industry has been carried out by IRL in recent times, but the funding for this project is now coming to a close with no available opportunity for continuation. Materials research for the construction industry is carried out by Scion (advanced wood products) and IRL (cements). Materials research for industry has been carried out in recent times predominantly by IRL and UoA. I do not believe there is any significant activity around novel recycling technologies for New Zealand-specific feedstock's in the New Zealand R&D sector at this time. Theme 3: Novel functional materials research is carried out by the MacDiarmid Institute, UoA and IRL.
Comments	Every major industrial economy is built upon significant engineering materials capability (steel, cement, plastics wood). These industries provide immobile foundations on which thriving economies can be built and expand from. Tax-payer investment in this area can be expected to remain within New Zealand for the life-time of the company. However the lack of capital within New Zealand means that new low-cost, low-capital technologies and approaches are important if such industries are to emerge and thrive in New Zealand. Joining up the investment reality within New Zealand with the targets of the scientific endeavour is key to the success of this challenge.

Entry ID	**417**
To increase the wealth of New Zealand by significantly increasing the export returns of smart high value innovative technologies	
Summary	The goal of this proposal is to increase returns of export products through the use of high value innovative technologies. Includes the following themes: (a) Develop advanced technologies to boost manufacturing productivity/competitiveness (b) Develop innovative and eco-efficient technologies for the production of advanced materials for industry and consumers (c) Improve data management in business using innovative digital technologies, smart information systems and complex system models for manufacturing (d) Significantly increase cross-sector collaboration and innovation, including consumer-driven design processes and commercialisation

Theme 1 Develop advanced technologies to boost manufacturing productivity and competitiveness utilising digital and information sciences, physics and biotechnology	
Importance to New Zealand	The primary outcome will be the enabling of the manufacture of high quality high value products, so as to increase the numbers of such products exported by New Zealand. This will result in direct growth of the productivity and prosperity of New Zealand. This results in creating economic wealth for New Zealand and improved employment opportunities for New Zealanders. The many indirect benefits from generating economic wealth include the ability to fund health, upgrade infrastructure and address social issues. By investing in this area, New Zealand is able to build upon its strengths in research and innovation. Future work will enable the development of novel and disruptive technologies that will transform the marketplace. New Zealand has strong capability in a host of areas. The benefits of work in these areas include: • Automation is highly relevant to primary industries such as meat and horticulture. Applying advanced automation technology to product handling for example will increase efficiency and throughput. • Tele-presence, where improved communication, audio and signal separation technologies will enhance listener experiences and add clarity and realism to long distance communications. These technologies will improve business function by reducing the need to travel. Meetings which currently take place in person will be able to take place remotely. • New wireless communication technologies will enable more reliable future niche broadband services and applications. • High temperature superconductor technologies promise to deliver greatly improved efficiencies to a wide range of industries. • A range of medical conditions and diseases are targeted by the discovery of new drug candidates. This activity is enabled by chemical and biochemical expertise.
Research components	The development of technologies for intelligent products shall require research in areas of electronics, biotechnology, pharmaceuticals, imaging, sensing, communications, ICT and medical devices. Some example research areas are: • High temperature superconductors requiring further research in the areas of wire development, cryogenic refrigeration, magnets, coils and devices, and power systems. • Robotics and automation, developing technology for handling, processing and sorting of primary produce. • In wireless communications, the development of cognitive radio will provide more robust communications through more efficient use of radio spectrum. • Tele-presence technology is underpinned by holographic audio. Here the tasks of rendering audio in 3D, creating personal audio zones and actively cancelling noise require research into spatial signal processing algorithms and acoustics. • Signal separation and classification algorithms, where mixtures of signals can be separated in the presence of noise and interference, require research in blind

	and statistical signal processing. • 3D sonar requires novel transducer technologies, multi-channel signal processing and electronic architectures. • New drug treatments can be derived from carbohydrate materials using the niche areas of glyco-therapautics and "iminosugar" chemistry. Iminosugar chemistry in particular could lend to building a library of novel chiral scaffolds for the pharmaceutical industry. • In carbohydrate nanotechnology, by isolating, synthesising, formulating and testing new carbohydrate-containing chemicals we can identify new candidates for the more effective cell-mediated vaccines.
Theme 2 **To develop innovative and eco-efficient technologies for the production of advanced materials for industry and consumers**	
Importance to New Zealand	The application of advanced materials has value to the agriculture, construction, communications, energy, and medicine sectors. The benefits from specific areas of research include: • Modelling of advanced materials which enable superior product design. • Future materials and structures, which shall drive the demand for efficient acoustic insulation systems. • Improvements of product design and micro-fabrication processes in the electronics industry underpin the rapid and commercially ready prototyping of new devices and functional materials. • Inorganic cementing systems which deliver equivalent performance to traditional Portland cement-based binders and standard construction mortars shall promote a greener image for the construction industry. • Making renewable polymers for use in paint and other industrial products. New Zealand can draw on its strong capability in the area to deliver this goal, which includes physicists, chemists, engineers, materials scientists, nanotechnologists and environmental scientists.
Research components	The area includes ceramics, biomaterials, nanotechnology, photonics, smart materials and polymers. Specific examples of research areas are: • For future materials and structures, the physics of wave propagation in meta-materials can be applied to develop high performance acoustic insulation systems. • High performance ceramics display unique combinations of properties such as high hardness, strength, thermal and physical shock resistance. Manufacture in New Zealand of new Si-Al-O-N ceramics with enhanced thermal and physical properties. • Micro-fabrication technologies enable the manufacture of micro-sensors, micro-fluidic channels, micro-machined piezo-ceramics, quartz and silicon etched devices and other 3-D structures with electrical connections. • New formulations of inorganic cementing systems. • For the modelling of advanced materials, research is required in nanotechnologies, computational materials design, materials characterisation and multi-scale modelling tools including new mathematical techniques in

	computational materials science. • Photonics involving the design, synthesis and characterisation of organic compounds and polymers of potential use as active components in all-optical switches. • Structural and dynamics materials testing: Mechanical testing of novel materials and structures; vibration, fatigue, water impact and shock testing; finite element analysis; and acoustics. • Renewable polymers for use in paint and other industrial processes using natural materials.
Theme 3 **Improve the management of data in business using innovative digital technologies, smart information systems and complex system models for manufacturing**	
Importance to New Zealand	The smart use of information is expected to streamline the day-to-day operations of New Zealand businesses and enhance the productivity of manufacturing processes. New Zealand can draw on a broad base of expertise to deliver this goal, which includes electrical and electronic engineers, computer scientists, information technologists, chemists and biotechnologists.
Research components	The areas of applications for digital technologies are in interactive systems, multi-platform media, creative industries, digital media creative design, content generation and imaging. Specific examples of smart information systems include: • Smart information systems allow high precision high throughput manufacturing of electrical components and nano-scale devices. • Computer vision enables the rapid creation of 3D content for objects and scenes; the development of calibration techniques for a wide range of imaging equipment; and 3D sensing and processing techniques such as pose estimation, triangulation, meshing, surface geometry estimation. • Mathematical modelling of industrial processes and systems such as experimental design, data analysis, heat and mass transport modelling and developing models to simulate physical systems. • New biotechnology synthesis methodologies for compounds such as sulphated oligosaccharides which play an important role in biological systems.
Theme 4 **To significantly increase cross-sector collaboration and innovation, including consumer-driven design processes and commercialisation**	
Importance to New Zealand	This theme both measures and increases innovation and networking. By bringing together of different parts of industrial and research to form highly networked private and public sector organisations, greater levels of innovation can be expected in New Zealand. Improved innovation will increase the competitiveness of industry, which faces pressures from high labour costs and fluctuating currency prices. Understanding the different components of New Zealand's innovation system and how they interact is thence important for increase our economic performance.

Research components	Research gaps for cross-sector collaboration and innovation and consumer driven processes lie in the areas of commerce, marketing and the social sciences. Specific examples of areas are: • Forecasting of present and future market demands. • Identifying and quantifying key aspects of collaboration and innovation, assessing New Zealand's present state of collaboration and innovation. • Identifying how New Zealand's levels of innovation, through collaboration, can be doubled in the next decade. • Systems and strategies for performing large-scale collaborations effectively and efficiently. Successful cross-sector projects require teams of individuals with a diverse range of skills and backgrounds. Teams must be well managed. • Processes to ensure achieving goals whilst meeting both business and research needs. • Policy incentives to motivate collaboration across and between sectors.
Research Gaps and Opportunities	The major gap in New Zealand in the high value manufacturing research sector is that the research funding is focussed on many, relatively small sized (around $1M) research projects, all of which are competing for funding. This does not encourage a collective view of high level outputs, or internal collaboration. These disadvantages could be addressed by combining the entire present high value manufacturing research sector into a single research platform. Such a platform would be analogous to the Hazards platform formed largely between GNS and NIWA. The high value manufacturing platform, in contrast, would cover Crown Research and university institutes, and could be covered by several future National Science Challenges.
Comments	The challenge focusses on high value products. It does not address the food and primary products industries specifically, although there are benefits of applying the research and development outcomes to these industries. It is primarily directed at areas which are not confined by New Zealand's land area, water supply or sunshine.

Entry ID	**446**
	Delivering a step change in high value added exports
Summary	The goal of this proposal is to research advanced materials and manufacturing to provide the basis for knowledge-intensive, high margin, globally competitive industries built on New Zealand's unique resources (materials and people).
Importance to New Zealand	New Zealand's exports are dominated by typically low value products based on our primary resources (dairy meat and logs). Many advanced nations build their economies from utilisation of minerals, exploit their nearness to large markets, and have large populations upon which to build their manufacturing expertise. New Zealand however has few non-biological resources in exploitable qualities, has a small population distributed across a nation with generally poor infrastructure, and is distant from most of its valued markets. The potential

<table>
<tr><td></td><td>opportunity for New Zealand to feed and provide underpinning materials to other nations can only be realised with the development of highly innovative solutions to address our specific domestic challenges; and by becoming more strongly integrated with global markets to ensure New Zealand products are valued.

Successful outcomes will lead to:
1. Increased value of our primary based exports through supplying into high need and high valued markets (food, semi and fully manufactured goods and consumer items with unique feature. (Note: the wood products industry believes that given the right underpinning technologies across the above areas, it can increase its exports from $4.5 billion to $12 billion by 2022.)
2. New technologies (e.g. productivity tools) to address the New Zealand issues and expert systems that have export value in their own right.
3. Spill-over benefits will include highly skilled and valued employment within New Zealand and strengthened communities protecting New Zealand’s unique cultural values</td></tr>
<tr><td colspan="2">Theme 1

Unleashing the new bio-economy - New high valued bio-products</td></tr>
<tr><td>Research components</td><td>Build new resource bases (e.g. expanded indigenous forests) that provide unique materials and strengthen New Zealand’s brand value in overseas markets.

Develop new industrial and fast moving consumer goods based on New Zealand materials that meet the values of the most demanding markets.

Industrial products from biological materials; high value food products; iconic New Zealand products from indigenous resources;

All underpinned by: World leading genetics, Biosecurity, Biological production systems (high sustainable production per ha), Industrial biotechnology, Smart and flexible manufacturing.</td></tr>
<tr><td colspan="2">Theme 2

New Zealand relevant production systems - Processing and supply systems</td></tr>
<tr><td>Research components</td><td>Build ‘virtual scale’ – develop distributed manufacturing systems that create the benefits of scale and maximise product value outcomes but can operate across a dispersed geographical base.

Develop smart and flexible manufacturing processes that can rapidly adjust to the needs of changing markets.

• Agritechnologies (robotics to precision tools) to substantially enhance productivity

Develop smart sensor and tracking technologies to provide the best possible stewardship and material management as demanded by the most discerning markets.

• Supply chain systems to overcome poor infrastructure and deliver world class product stewardship (including packaging)</td></tr>
</table>

Theme 3 Expert systems	
Research components	Build new expert systems, including modelling tools, precision technologies and productivity tools that support the above and become valued, saleable products in their own right. • Data management and processing systems • Sensor technology and operations research • Visualisation and modelling tools for 'big data'
Theme 4 Global connectivity - Partnerships for value	
Research components	• Global Science partnerships • Global Market foresight – market preferences • Global manufacturing partnerships
Research Gaps and Opportunities	To date, the concept of virtual manufacturing has to date not been addressed in New Zealand. The underpinning competencies, such as global partnering with a focus on strengthening manufacturing in New Zealand and ensuring best positioning of New Zealand products in high value markets, is currently poorly developed. There are important national capabilities feeding into the above including: advanced genetics, increasing biological productivity and expanding our biological production base and data management.

Entry ID	456
Developing New Manufacturing and Materials Capabilities - Developing new manufacturing and materials capabilities so that by 2030, 20% of our exports will comprise advanced materials and creative high-value, high-technology products and processes, based on New Zealand's innovative intellectual capacity	
Summary	This proposal has a goal of catching up with the per capita incomes of other first-world countries, by leveraging off the traditional strengths of New Zealand industries and exploiting the current national infrastructure related to primary (agricultural) industries. The research programme proposes the following themes: (1) Novel Agri-Technologies - Machine vision research for horticultural products (harvesting, fruit grading, meat processing); forest machinery such as remote logging and retrieval systems (2) Biomaterials - develop intellectual capital to create high-value biomaterials derived from New Zealand's natural resources or from innovative synthetic

	pathways (e.g. tissue scaffolds; prosthetics, etc.) (3) Information and Communications Technologies - develop a thriving New Zealand export economy based on software, communications hardware, etc. (4) World-Class Manufacturing Niches - Processes for identification of economic potential; design & manufacture off-shore (exploiting 3D design) etc.
Theme 1 **To create an export economy based on unique New Zealand products, process and product solutions in agri-technology, including forestry and fishing**	
Importance to New Zealand	New Zealand has a long history of primary industry expertise but has relied too much on the export of primary (logs) or commodity (dairy) products. To catch up with the per capita incomes of other first-world countries, including our nearest neighbour, Australia, we will need to leverage this expertise to derive far higher earnings per worker. Our best opportunity for achieving this is to build off the traditional strengths of New Zealand industries because there is a great deal of existing science and engineering research infrastructure that has already been established to support this. New Zealand does not possess an extensive manufacturing base in computer hardware, automobiles or aviation, for example, and it would be difficult to establish significant new industrial players in these areas. On the other hand, we should be able to exploit the current national infrastructure related to primary (agricultural) industries and build smart technologies based on this.
Research components	Machine vision research for horticultural products (harvesting, fruit grading, meat processing); forest machinery such as remote logging and retrieval systems; GPS systems for animal management; automated milking robots; smart fencing systems for communications; irrigation systems; farm management software; agricultural power generation.
Theme 2 **To develop intellectual capital to create high-value biomaterials derived from New Zealand's natural resources or from innovative synthetic pathways**	
Importance to New Zealand	Unlike many high-tech industries, biomaterials do not require extensive mineral resources to create a success industry but instead are based upon low-volume, high-value products that rely on high-technology, scientific (medical) intellectual capacity and innovation. These factors mitigate the barriers of distance from market for the development of new commercial ventures. At the same time, New Zealand has a significant base in biological sciences, leading medical researchers and world-class engineering schools, all of which can contribute to the creation of a science-based biomaterials industry. Furthermore, trends of greater demand for improved healthcare, new technical capabilities in materials manufacture and analysis, the ageing populations in Western societies and growing affluence of the Asian Tigers (China and India) all support the growth of biomaterials as an opportunity over the next few decades. There is no reason why New Zealand cannot exploit these trends – indeed, in this

	area, we are limited largely by our ability and willingness to create the intellectual capital necessary to support innovation.
Research components	Tissue scaffolds; prosthetics; dental implants; self-assembling peptides for tissue replacement; bone and joint replacement; controlled release drug delivery; cochlear implants; eye lens replacement; artificial skin; heart-assist devices and pacemakers; visual cortex stimulators; extra-corporeal devices e.g. dialysis systems; arterial stents; new polymers with controlled properties; metallic and ceramic materials; corrosion; toxicity; biocompatibility; stem cell delivery and support scaffolds; surgical equipment; etc.
Theme 3 **To develop a thriving New Zealand export economy based on software, communications hardware and health, education, emergency services and security information technologies**	
Importance to New Zealand	As noted in other themes described under this goal, New Zealand faces constraints in terms of distance from market and its relatively low mineral resources. At the same time, there is an environment of existing and rapidly increasing global connectivity, particularly through the internet, a growing trend for cloud-based storage of information and delivery of computer application packages and the ubiquitous nature of smart phones and "always connected" personal computer devices. This environment, plus our world-class education system for computer scientists and engineers offers New Zealand the opportunity to overcome its relative isolation and to nurture a new export platform based on information and communication technologies.
Research components	Computer architecture; software engineering; satellite communications; internet protocol development; information security and encryption; electronic commerce systems; mobile apps; location-sensitive applications; human-machine interfaces; interface and cognitive psychology; computer gaming; social networks; personal data storage and security; large data handling; long-range wireless communications; optic fibre data systems; parallel computing; etc.
Theme 4 **By 2030, 20% of New Zealand exports will be based on products that leverage export manufacturing benefit from niche areas of expertise, such as fisheries, adventure tourism, health tourism, film industry, marine craft, and rugby**	
Importance to New Zealand	Globally, the manufacture of high-value products is an intensely competitive and crowded space. It will be important for New Zealand to identify niche areas in which we can take world-leading positions that are consistent with our unique environment – low-density population, distance from market, beautiful natural surroundings, significant coastline and ocean resources, etc. New Zealand cannot rely on the export of primary products or growing the tourism and service industries to regain a standard of living commensurate with other leading Western countries because the income per worker is simply insufficient to do so. Therefore, we must exploit high-value products and processes that offer high earnings per worker. However, to sustain a competitive advantage, we must base

	such exports on areas that align with our unique environment (social, geographic, demographic), rather than compete head-to-head with established economic powerhouses.
Research components	Processes for identification of economic potential; design & manufacture off-shore (exploiting 3D design); 3D printing technologies; building clusters to share distribution channels/supply chains; diversification of risk; provision of intellectual capital (education); bridging the research-to-commercialisation gap; economic structures that sustain New Zealand ownership and location; etc.

Entry ID	**474**
High Tech "New Zealand Inc." **Creating an agile, high-value, high wage economy**	
Summary	The goal of this proposal is to Increase the proportion of digital technology-based export revenues. The proposed research programme includes the following theme: of (1) achieving scale in novel digital technology-based businesses through collaboration (2) creating a high value/innovation workforce and understanding of emerging economic opportunities based on novel technologies (3) accelerating growth of niche high tech/high value manufacturing clusters including medical devices and technologies, novel materials, niche manufacturing and agritech (4) establish a pharmaceutical industry in New Zealand by 2020 that utilises New Zealand's medical biotechnology experience and expertise to develop new therapeutics
Theme 1 **Achieving scale in novel digital technology-based businesses through collaboration**	
Importance to New Zealand	Increase in proportion of digital technology-based export revenues where revenue per unit cost of production is >10 times the average of our dairy, meat, fishing and forestry industries (or similar)
Research components	Developing capabilities in cloud, photonics and emerging digital and information technologies that can transform New Zealand businesses 2.1.2 Defining business models and support mechanisms for software-based businesses to grow export revenues, including access to research and technology capabilities via national collaborative mechanisms

Theme 2 Creating a high value/innovation workforce and understanding of emerging economic opportunities based on novel technologies	
Importance to New Zealand	Increase in highly skilled and highly paid workforce with incomes >5x average wage under the age of 40 (by x% by 2025 or similar) Increase in labour market productivity (by xyz by 2025 or similar)
Research components	Defining key characteristics of innovation/lifelong learning specific to New Zealand to enable us to respond to changing technology, and the continually evolving needs of the workforce 2.2.2 Defining how we can build an e-society that converts existing weaknesses such as remoteness and sparseness into strengths, provides better services to communities, leverages environmental, health, agricultural and other data into opportunities for growth and prosperity. Defining internationally competitive models for development and retention of highly-skilled and mobile workers and potential interventions that could be applied in New Zealand to expand the highly-skilled and highly-paid proportion of our workforce.
Theme 3 Accelerating growth of niche high tech/high value manufacturing clusters including medical devices and technologies, novel materials, niche manufacturing and agritech	
Importance to New Zealand	Increase in proportion of elaborately transformed manufactured goods export revenues with double the average of export $ per Kg product sold (by 25% by 2025 or similar)
Research components	Establishing national technology platforms in medical devices and technologies, novel material and niche manufacturing technologies and agritechnologies to link existing capabilities, define and fill capability gaps and create new science and technology-based business opportunities
Theme 4 Establishing a pharmaceutical industry in New Zealand by 2020 that utilises New Zealand's medical biotechnology experience and expertise to develop new therapeutics	
Importance to New Zealand	New Zealand pharmaceutical and therapeutics industry worth at least $1 billion in capital value and employs at least 1000 people by 2020 Lower cost of drugs developed for priority New Zealand diseases
Research components	Developing capability for taking drug and other therapeutic discovery leads from phase 1 to phase 3 clinical trials in specific diseases of importance to New Zealand. Use New Zealand priority diseases as models for development and commercialisation of pharmaceutical and other therapeutic compounds including business models to both reduce New Zealand health care costs and capture value from international markets 2.4.2 Establishing a national platform to link existing drug and therapeutic development programmes, fill critical gaps in clinical development and interface with both the manufacturing and investor communities

Research Gaps and Opportunities	New Zealand has the potential to be an agile high-tech exporter generating high value products and services that support high wage enterprises. To achieve this we need to leverage our human capital (including our advanced research and development capabilities), share resources and collaborate to develop centres of excellence in niche areas of current and potential competitive advantage

4 Increasing productivity

The submissions in this group are shown with their underpinning themes in the table below. Each submission follows in full.

Table 2: Summary of proposed challenges and themes

Entry Id	Challenge	Themes
91	Advancing mechanisation and automation of New Zealand's agricultural and horticultural sectors to overcome constraints in intensification and expansion induced by decreasing supply of skilled and unskilled labour.	1. Identify how changes in crop morphology (of trees, vines, row crops) and new mechanisation and automation may be combined to solve New Zealand's primary production labour supply problem 2. Identify key issues of individual animal (cow) behaviour or physiological variables that when continuously monitored, support optimal herd management by providing higher productivity and ensuring animal well-being
261	Productive plants for a profitable and sustainable New Zealand. Plants are essential for human life and contribute to 70% of New Zealand exports. We need smart, flexible and profitable primary production in a changing world to feed an increasing population sustainably."	1. Understanding plant biological processes. To gain a fundamental and systems-level understanding of plant processes. This will allow plant scientists to rapidly translate results to commercially relevant species 2. How a diverse, changing environment affects productivity in different plants. To link genetic potential of high yielding varieties to different changing environments. Capitalise on second-grade land and identify new crops suited for New Zealand conditions 3. To produce high yielding profitable crops in a sustainable manner using targeted molecular breeding, synthetic biology and biotechnology 4. Engage communities and create a new generation of plant biologists: To create education strategies to produce the next generation of world leading plant scientists in New Zealand. This work will be carried out in an engaged society keen embrace new technologies
316	To capture a proportion of the 1.6 million bobby calves slaughtered within their first two weeks of life and rear for beef production. If 50% could be reared this has potential to add $1 billion in farm gate returns to New Zealand agriculture	Rear at least 50% of the 1.6 million dairy calves presently born on New Zealand dairy farms and not reared at present

<table>
<tr><th>Entry ID</th><th>68</th></tr>
<tr><td colspan="2">Scalable cognitive systems for high value knowledge extraction using cloud technologies</td></tr>
<tr><td>Summary</td><td>Scalable learning algorithms. Combine existing machine learning techniques with cloud technologies to allow automatic scaling of computational learning. Flexible resources based on the demands of incoming data need to be developed.</td></tr>
<tr><td colspan="2">Theme 1

Scalable learning algorithms. Combine existing machine learning techniques with cloud technologies to allow automatic scaling of computational learning. Flexible resources based on the demands of incoming data need to be developed</td></tr>
<tr><td>Importance to New Zealand</td><td>The world's economy is shaped by information. As our networks get faster and more devices produce more data, the ability to detect trends and patterns becomes an extreme competitive advantage. Machine learning already guides investment, high frequency trading, and optimization of manufacturing and logistics, but is usually constrained to a highly specialised and filtered data stream. Ability to scale will improve the domain and scope of patterns that may be detected. New Zealand can either import these capabilities in 5-15 years to remain viable in the global economy, or invest now to become a leader and exporter of high value machine learning technology</td></tr>
<tr><td>Research components</td><td>Take existing machine learning algorithms: Neural networks, genetic algorithms, and other classification/prediction techniques, and convert them to horizontally scalable computing platforms. This includes infrastructure for automatic deployment of resources across on-demand cloud servers, or commodity hardware. This would involve identifying which algorithms are most amenable to being scaled. Collaboration with businesses that deal with high data throughput, and previously unable to employ online machine learning, will provide opportunities for adding value to their market needs using classification and pattern detection technologies.

Ethics, tolerance and safety of on-line and shared data and the new breed of AI algorithms that will manipulate user's data autonomously.</td></tr>
<tr><td colspan="2">Theme 2

Ethics, tolerance and safety of on-line and shared data and the new breed of AI algorithms that will manipulate user's data autonomously</td></tr>
<tr><td>Importance to New Zealand</td><td>As large scale data aggregation and analysis becomes part of corporate and government assessment of individuals, it is important to have an ethical framework to address privacy concerns and set boundaries for where predictive technology can and can't be used. As these predictions become more accurate, and as they encroach of all areas of our lives, there will be more concern about whether technology liberates us, or results in a dystopia of prejudged outcomes. New Zealand is often seen as a free country, but it is important to ensure these technologies improve our lives</td></tr>
</table>

Research components	A look at both technical and ethical best practices for data management, e.g. how to anonymise individuals so that they can't be identified later. Stable goal systems - as artificial intelligence systems become more flexible in the learning technology, we need to focus on the ability to have certainty or high confidence in the outcomes. Robotics and embodiment of intelligence. Cognitive systems face the challenge of learning information that is grounded in real-world experiences.
Theme 3 **Robotics and embodiment of intelligence. Cognitive systems face the challenge of learning information that is grounded in real-world experiences**	
Importance to New Zealand	In the same way that computers have moved from institutional resources to personal and individualised tools, robotics will do the same in the next 5-15 years. Low cost robotics will open many possibilities. For example, in manufacturing, companies and processes that were once too small to afford robotics will become viable; and in science, where mobile low cost quadcopters can make large scale environmental monitoring autonomous. If New Zealand is correctly placed during this transition, it has the possibility to benefit economically and socially through the deployment of embedded software that can control these robotic technologies
Research components	Building low cost control systems that will run on cheap commodity hardware. This involves algorithmic research into real-time kinematic calculations with efficient use of computational resources. Simulation tools for robotic agents, allows for easy iterative testing of control systems, rapid development of robotic platforms and identification of industry needs, and without high cost outlay. Goal directed behaviour and planning. Closely linked with aspects of Theme 1 and 2, this will involve designing decision making and planning algorithms that are also efficient enough for cheap embedded hardware. 1. While cloud technologies are widely used in industry, academic machine learning algorithm research quite often based on smaller datasets that can be explored on a single desktop. These days, industrial applications are more networked and distributed, and this not only allows correctly designed learning algorithms to address larger data problems, but can provide fault tolerance, redundancy, and automated scaling and provisioning of computing resources. 2. Data protection and user privacy is becoming increasingly of interest to consumers and users. Addressing their concerns will lead to policy advisement and industry best practise for the use and collection of private data, from a sound information theoretic perspective. Recent industry and government data breaches makes it clear that these are still not well understood, even among supposed industry experts. 3. Research into how to convert previous specialised control systems, and taking advantage of the wave of cheap hardware platforms such as Arduino, Parallax and other microcontrollers, will provide a solid foundation for industrial application. Much time is spent understanding the environments and components available to engineers, as a result of this theme would be integration with standard open

	frameworks such as ROS (Robot operating system) that can provide a unified framework for assessment of the best platform for a particular application.
Research Gaps and Opportunities	1. While cloud technologies are widely used in industry, academic machine learning algorithm research quite often based on smaller datasets that can be explored on a single desktop. These days, industrial applications are more networked and distributed, and this not only allows correctly designed learning algorithms to address larger data problems, but can provide fault tolerance, redundancy, and automated scaling and provisioning of computing resources. 2. Data protection and user privacy is becoming increasingly of interest to consumers and users. Addressing their concerns will lead to policy advisement and industry best practise for the use and collection of private data, from a sound information theoretic perspective. Recent industry and government data breaches makes it clear that these are still not well understood, even among supposed industry experts. 3. Research into how to convert previous specialised control systems, and taking advantage of the wave of cheap hardware platforms such as Arduino, Parallax and other microcontrollers, will provide a solid foundation for industrial application. Much time is spent understanding the environments and components available to engineers, as a result of this theme would be integration with standard open frameworks such as ROS (Robot operating system) that can provide a unified framework for assessment of the best platform for a particular application.
Comments	Theme 1 is looking at how to expand localised algorithms to scale to large networks of cloud servers. Whereas Theme 3. is looking at how to move from highly specialised and expensive algorithms to low cost embedded systems. This serves as a nice contrast between distributed growth and localised efficiency, which will hopefully provide the challenge with a valuable contrast of concepts and opinions.

Entry ID	**91**
Advancing mechanisation and automation of New Zealand's agricultural and horticultural sectors to overcome constraints in intensification and expansion induced by decreasing supply of skilled and unskilled labour	
Summary	Goal is to increase mechanisation and automation of New Zealand's agricultural and horticultural sectors to overcome intensification/expansion constraints. It proposes to do this by research programmes to identify (a) physiological and commercial viability of alternative or new growing systems how morphology and crop growth could be altered to optimise the labour: productivity ratio by facilitating mechanisation and/or automation, for labour-intensive operations (b) key issues of individual animal (cow) behaviour or physiological variables that when continuously monitored, support optimal herd management by providing higher

	productivity and ensuring animal well-being
Theme 1 **Identify how changes in crop morphology (of trees, vines, row crops) and new mechanisation and automation may be combined to solve New Zealand's primary production labour supply problem**	
Importance to New Zealand	Demand for labour in New Zealand's horticultural industry is increasing, and requirements include strength (eg apple picking) and skill (eg pruning). Orchard and vineyard locations tend to be remote from cities and large towns, and seasonal labour is limited in quantity, skill and reliability. Examples: New Zealand's $300 million pip fruit export industry has in-orchard costs of around 30% and most is associated with thinning and harvesting; labour intensive operations. The kiwifruit industry recognises labour as an on-going "critical" issue and cost[1]. Mechanisation and automated systems will support farmers and growers by substituting labour by machines and ICT, to simultaneously increase productivity and product quality as well as lowering environmental impact through more precise activities and management of crop and fruit production. The resulting systems or key-components may also be expanded to deliver solutions to international markets as some face similar challenges. [1]http://researcharchive.lincoln.ac.nz/dspace/bitstream/10182/862/1/aeru_rr_311.pdf
Research components	Analyse growing systems (trees, vines, row crops) to characterise morphology versus production/quality. Investigate physiological and commercial viability of alternative or new growing systems such as espalier, T-bar and lie-flat. Identify with biological fundamental knowledge (physiology, yield formation) how morphology and crop growth could be altered to optimise the labour: productivity ratio by facilitating mechanisation and/or automation, for labour-intensive operations such as pruning, thinning and harvesting. Pursue pragmatic combinations of new growing systems, labour-saving structures, manual aids, mechanisation and automation. Identify knowledge gaps for further research. The research needs to be conducted in a multi-, inter- and trans disciplinary way. It has to involve research knowledge from disciplines that include fruit crop physiology, horticulture, (bio-)informatics, image analysis, robotics, agro-ecology, agricultural engineering, industrial sensor development, complex signal processing, (wireless) sensor networks, precision agriculture and ICT for agriculture.
Theme 2 **Identify key issues of individual animal (cow) behaviour or physiological variables that when continuously monitored, support optimal herd management by providing higher productivity and ensuring animal well-being**	
Importance to New Zealand	Dairy production demands multi-skilled labour (eg dairy farm assistants) who can manage complex problems such as ensuring animal well-being, managing grassland paddocks in a changing climatic environment and achieving goals set by society for the farm-environment interaction. Yet sourcing labour for dairy farms is an increasing challenge.

	Mechanisation and automated systems can substitute for some labour and provide decision support through sensing and ICT in particular. Modern sensor systems for grassland, animals and environment – some available, other being developed internationally –will allow increasing productivity by better management and increasing product quality. In addition, better animal wellbeing and reduced environmental impact will result from more precise activities (eg water and fertiliser placement) and management of herds. This will be enabled by increasing the knowledge of the herd as an entity (or of its sub-groups), but mainly by monitoring individual animals. Detecting behaviour and relevant physiological variables of individual or representative animals is the next level of productive and animal welfare to advance livestock production. This needs to be supported by mechanisation and automation in grassland management, feed supply and effluent management. The resulting systems for individual animal monitoring (IAM) or key-components of IAM may also be exported as some face similar challenges.
Research components	A key aspect is to understand the biology as well as the interactions of animal movement related to animal behaviour. Linking animal behaviour with animal (cow) conditions (e.g. wellbeing, productivity, general and special health conditions, heat ...) by identifying typical patterns of behaviour and linking to productivity, physiological conditions and health, and deriving basic principles to define minimum sets of variables to assess sufficiently individual or herd conditions. Developing of sensors and multi-sensor systems to reliably monitor movement and physiological variables of the individual animal in time and space. Develop robust systems to exchange data/information, continuously automatically service sensors (calibrate and recharge) between sensors and herd-information system of the farmer. Developing fast and robust methods to analyse vast amounts of data resulting from continuously monitoring of animal (movement, physiological variables) over time and space. Identify knowledge gaps for further research. The research has to be conducted in a multi-, inter- and trans disciplinary way. It has to involve research knowledge form disciplines as animal physiology, ethology, animal health, (bio)-informatics, agricultural engineering, industrial sensor development, complex signal processing, (wireless) sensor networks, precision agriculture and ICT on agriculture.
Research Gaps and Opportunities	1. Analyse growing systems for the express purpose of changing growth habits and morphology such as espalier, T-bar and lie-flat to facilitate mechanisation in fruit production. 2. Investigate manual orchard/vineyard operations and determine where (i) mechanisation and (ii) automation can relieve or increase productivity and quality of labour-intensive operations such as pruning, thinning and harvesting. Consider pragmatic/economic combinations of new growing systems, labour-saving structures, manual aids, mechanisation and automation.

	3. From (2), develop systems, mechanisation and automation to meet the recommendations identified by (1) and (2). 4. Identify keys in genomics, phenology and physiology of the various crops to define new goals in plant breeding as well as in crop husbandry to adapt crop canopy for enhanced mechanisation and automation with increased yields and quality of products (rootstock selection, spacing, mechanical structures, irrigation and fertilization, growth control ...) 5. Analyse the interaction of environmental variables, animal health and animal behaviour in different dairy production systems. Develop new methods and indicators to analyse the vast and complex sets of data (from one animal, and from herds of 300 animals or more) identify sensitive situations in the productivity, health and social aspects in the herd by sensing variables of the individual animal. 6. From (5), develop systems, mechanisation and automation to meet the recommendations identified by (4) and (5).

Entry ID	**261**
Productive plants for a profitable and sustainable New Zealand. Plants are essential for human life and contribute to 70% of New Zealand exports. We need smart, flexible and profitable primary production in a changing world to feed an increasing population sustainably	
Summary	The goal is to increase plant productivity by improving the efficiency of agricultural plants. This is proposed through a research programme with themes including: (a) understanding plant biological processes (b) understanding how a diverse, changing environment affects productivity in different plants (c) produce high yielding profitable crops in a sustainable manner using targeted molecular breeding, synthetic biology and biotechnology and (d) engaging communities and creating a new generation of plant biologists:
Theme 1 **Understanding plant biological processes. To gain a fundamental and systems-level understanding of plant processes. This will allow plant scientists to rapidly translate results to commercially relevant species**	
Importance to New Zealand	The biological processes of many beneficial traits in plants remain unknown, our lack of knowledge of these, threatens our future wellbeing. A co-ordinated effort into understanding basic biological processes is needed before step changing commercial gains can be achieved in our crop systems. Plant breeding does not yet incorporate detailed biological knowledge into crop improvement, this may be due to either lack of knowledge or ability to translate into a crop system. These two features need to be addressed to increase yield and quality which will

	ultimately achieve a price premium for New Zealand growers. Reductionist methods need to be linked with holistic approaches, combining deep knowledge of individual biological components with understanding of whole systems. Finally, plants share many processes in common with other life kingdoms; we expect there will be significant transfer of knowledge to other branches of the life sciences including human health. A document that lays out the direction of US funded plant research has influenced some of the concepts proposed in this challenge is “The Green Frontier: A Unified Vision for Plant Research”. This was generated at the Plant Science Research Summit held in the Howard Hughes Medical Institute 2011. Potential measures: Predictive models to enable us to manipulate key plant biological traits of economic importance. Enhanced international reputation to leverage global research collaborations.
Research components	1. Develop a basic plant science research effort to understand at a molecular and cellular level (from DNA to proteins to metabolites) the regulation of key biological traits of economic importance. 2. Use holistic approaches to link molecular and cellular data with whole plant performance: Select relevant plant species and assess performance in controlled environments (physiology). 3. Develop modelling tools to predict plant growth and development for different crop species. 4. Research knowledge gained in this theme will be leveraged into crop varieties to improve crop performance in a set environment (theme 2), yield and quality (theme 3). Research Gaps and Opportunities: The production of high value plant-based products and foods for health rely on a thorough understanding of the metabolic pathways that produce these products. There is a huge deficit in funding of fundamental research in plant biology in New Zealand, more is needed to better understand our crop systems. Topics that need to be addressed to improve productivity include: Photosynthesis, carbon allocation and yield, nutrient utilisation, fruit development and ripening, flowering and bud break, architecture, response to the environment, and disease resistance. Detailed phenotyping (phenomics) facilities are expensive but there are opportunities to partner with the Australian phenonomics facility in Adelaide. In addition, there are opportunities to join with international research groups in particularly the US, Europe and China which have large initiatives that can complement this research. Some work is already underway in New Zealand in the CRI and University sectors.
Theme 2 **How a diverse, changing environment affects productivity in different plants. To link genetic potential of high yielding varieties to different changing environments. Capitalise on second-grade land and identify new crops suited for New Zealand conditions**	
Importance to New	Many of the world’s ecosystems that support human societies are over-exploited and unsustainable. Climate change could exacerbate these environmental

Zealand	problems by adversely affecting water supplies and increasing the frequency of drought and floods, New Zealand is no exception. Firstly New Zealand has a unique ecosystem, by tailoring crops to each location we will get maximum yield and find the best commodity crops for each environment. Secondly we need to grow production sectors by improving the crops to allow them to grow profitably in as yet unexploited farmlands. Potential measures: High yielding crops customised to different environments with greater resilience to biotic and abiotic stresses and reduced inputs. High value crops allowing a doubling of export value over the next 30 years.
Research components	1. Investigate diversity in our major crops and in potential new crops by detailed phenotyping of growth and yield of different crop varieties in controlled and field environments through phenomics (phenotyping). 2. Sequencing genomes of crop plant varieties and linking this genetic variation with phenomics to determine gene/environment interactions. 3. Interdisciplinary research understanding plant/microbe/soil/environment interactions. 4. Extension of predictive models from controlled environments to field conditions in different New Zealand environments 5. Trialling imported plant varieties and species that can replace commodity crops that may become non-economically viable due to increased transportation costs and environmental changes and supply information to growers about the optimal crops for their region. Research Gaps and Opportunities There have been great advances in technologies that have allowed relatively cheap sequencing of genomes of non-model crops. We now have an opportunity to build on these resources for crop improvement. A unique opportunity for New Zealand researchers is access multiple research sites across the country, allowing multiple environments to be tested simultaneously.
Theme 3 **To produce high yielding profitable crops in a sustainable manner using targeted molecular breeding, synthetic biology and biotechnology**	
Importance to New Zealand	Yield is often a limiting factor in our primary production sector, for example the dairy industry is limited by amount of pasture and other plant based feed. For other crops, the biomass needs to be directed into a unique tissue in the plant. New Zealand is internationally known for fruit and vegetable crops that generate a high price premium, for example kiwifruit, wine grapes, onions and carrots and quality apples. For each of these, yield (amount) and quality (e.g. flavour development) is controlled by internal signals in the plants such as flowering time and carbon allocation, as well as environment. By applying our understanding of the way the plant directs these resources learned in theme 1, and react to their environment (theme2) we will improve quality and increase productivity in this sector. Finally many crops are heavily sprayed and fertilised, to the detriment of the environment and at high expense,

	reducing these without loss in yield is a priority to maintain market access and the clean green image of New Zealand. Potential measures: Increased high value export crops and plant products produced in a sustainable way. This will increase grower price margins by obtaining larger yields at lower production costs allowing competitive pricing in the global environment.
Research components	1. Translate and test fundamental knowledge gained into selected crop varieties in a highly targeted way to improve crop yield and quality using molecular breeding and/or biotechnology 2. Carry out field trials of novel improved cultivars to test plant productivity and environmental resilience. 3. Test cropping systems and new varieties with low nutrient requirements and disease resistance.
Theme 4 **Engage communities and create a new generation of plant biologists: To create education strategies to produce the next generation of world leading plant scientists in New Zealand. This work will be carried out in an engaged society keen embrace new technologies**	
Importance to New Zealand	New Zealand earns a living through the plant based industries of the pastoral, horticultural, forestry and crop sectors, with 70% of exports relying either directly or indirectly on plants. To create productive plants for a profitable and sustainable New Zealand, we need to inspire the next generation of researchers and engage the public. Throughout history there have been times when plants have failed, resulting in food shortages especially during times of extreme climate. The green revolution changed this, with the ability to store and transport food there is now a degree of food security. However populations are still increasing, we need to embrace the new revolution, the DNA revolution, to feed the next generations. This theme aims to build a resource of plant researchers to be able to creatively address the challenges ahead, and research ways to educate the public more efficiently on the potential of this technology. Plant science is becoming increasingly interdisciplinary and breakthrough and innovative solutions will occur at the interface of physiology, genetics, biochemistry, development, ecology, bioengineering and computational biology. The undergraduate and postgraduate programmes need to be less compartmented and embrace interdisciplinary research. Potential measure: Increased number of smart multidisciplinary plant researchers that can operate in an engaged society keen to embrace new technologies.
Research components	1. Develop, trial and assess programs on developing transferable skills in creative science thinking and critical thinking. 2. Develop programs and resources to engage and educate New Zealanders about plant potential and assess their impact on the level of community knowledge and engagement with plants and modern plant breeding methods. This could be trialled through museums and or showcase GE farms

	Research Gaps and Opportunities Leverage off international modules on fostering creative scientific thinking and critical thinking. Other comments: Create realistic career paths for plant scientists by developing undergraduate and postgraduate programs that include different disciplines and raise current challenges faced by New Zealand. Increase number of Scholarships/internships abroad Promote bridges across academic disciplines. In the last 4 years there has been a drop in the number of postgraduate scholarships available for plant research in New Zealand. Organisations that used to offer scholarships but no longer do include TechNZ, AgMardt, FRST/MBIE. We need to have some new alternatives. We need to raise awareness of the value of plants by including more plant science into high school and the use of relevant plant examples.
Research Gaps and Opportunities	Please kindly see each theme for the research gaps and opportunities
Comments	Contributors to this submission: [names and affiliations removed: OIA: 9(2)(a)]

Entry ID	**316**
To capture a proportion of the 1.6 million bobby calves slaughtered within their first two weeks of life and rear for beef production. If 50% could be reared this has potential to add $1 billion in farm gate returns to New Zealand agriculture	
Summary	The goal is to obtain greater economic benefit by rearing a % of bobby calves that are currently slaughtered on dairy farms for beef production instead. The proposed research programme includes the following themes: (1) sexed beef semen available to dairy farmers at competitive prices (2) genetic potential of beef bulls used by dairy industry have been progeny tested and screened for genomic selection breeding values in particular ease of calving and short gestation length (3) evaluate the business value proposition for coordinated supply chains from semen to beef products (4) evaluate new products that suit dairy beef production (5) evaluate new and novel forages that ensure animal live weight gains are maximum all year round (6) ensure the environmental footprint is not compromised by this beef production
Theme 1 **Rear at least 50% of the 1.6 million dairy calves presently born on New Zealand dairy farms and not reared at present**	
Importance to New Zealand	Generate revenue (estimated $1 billion in farm gate returns) Alleviates a potential negative impression of the dairy industry (ie slaughter of week old calves) generates employment for agricultural and associated industries such as

	transport, stock and station industries, meat processing industries, and meat by-product industries such as pharmaceutical company's Generate opportunities for agricultural business to cooperate in the supply chain by making this happen
Research components	1. Sexed beef semen available to dairy farmers at competitive prices 2. Genetic potential of beef bulls used by dairy industry have been progeny tested and screened for genomic selection breeding values in particular ease of calving and short gestation length 3 Evaluate the business value proposition for coordinated supply chains from semen to beef products 4 Evaluate new products that suit dairy beef production (meat, by-products and neutraceuticals) 5 Evaluate new and novel forages that ensure animal live weight gains are maximum all year round 6 Ensure the environmental footprint is not compromised by this beef production
Research Gaps and Opportunities	Accuracy of sexing semen and ease of doing so in New Zealand (to ensure majority of calves raised are males) Farm systems that can profitably rear and farm dairy beef animals to slaughter use of novel and new forages and sustainable farming practices that ensure beef production is environmentally sustainable
Comments	Although this project is not new it has not been addressed in a co-ordinated approach in the past

5 Minerals

The submissions in this group are shown with their underpinning themes in the table below. Each submission follows in full.

Table 3: Summary of proposed challenges and themes

Entry Id	Challenge	Themes
88	To generate wealth from petroleum resources in the exclusive economic zone	1. Understanding the prospectivity of the sedimentary basins in the EEZ 2. Develop an agreed system for evidence based decision making to include in legislation 3. Managing the risks to the environment from offshore oil development
147	To explore the geology and geophysics of our offshore basins so we improve our knowledge of their resource potential and their tectonic history	1. Carry out geological exploration of our offshore territory. 2. Carry out exploration of basins and structures close to land.
247	Establishing a research and development project that explores the potential of South Island Silica deposits	Establish the value of South Island silica deposits
307	Wealth and Security from Geological Resources	1. Prospectivity to prosperity - facilitating greater exploration of our extensive Exclusive Economic Zone, so enhancing the discovery of new reserves of petroleum and minerals, leading to significant improvement in the New Zealand economy 2. Security of supply – ensuring New Zealand is resilient to global restrictions on the availability of strategic energy and minerals resources 3. Stewardship – minimising environmental impact whilst realising the full benefits of our natural endowment of geothermal energy, petroleum, mineral and groundwater resources
328	Turbocharging New Zealand's economic growth and future-proofing our economic resilience and global competitiveness by bringing forward the managed exploration and development of oil and gas resources within our vast Exclusive Economic Zone	1. Understand, map and communicate the petroleum prospectivity of New Zealand's basins, thereby reducing subsurface technical risk and geological uncertainty, leading to accelerated exploration activity and new oil and gas discoveries 2. Overcoming barriers to, and managing risks associated with, the development of New Zealand's petroleum resources, to enable generation of new wealth for New Zealand in a socially and environmentally acceptable manner

Entry Id	Challenge	Themes
335	The Challenge is that New Zealand's past economic performance has been poor. The goal of this challenge is to develop larger and more diversified export income sources to make the New Zealand economy more resilient and prosperous.	1. To develop technologies to enable extraction of petroleum, minerals and materials with novel properties from our marine, undersea and underground resources in an environmentally responsible manner 2. The goal is to use leading edge information and communication technologies to embed unique functionality in a range of products, processes and services 3. The goal is to advance multidisciplinary product development methodologies drawing on design, engineering, technology and science expertise 4. The goal is to create novel materials and processes from which to build transformative technology platforms that disrupt markets, are less hazardous, or render obsolete products made by others
378	Environmentally-responsible intensification of land and water-use, in relation to New Zealand primary industries , to benefit the economy and society	Increased minerals exploration and development on land, via improving New Zealand's attractiveness for investment
379	Environmentally-responsible identification of and development of resources within New Zealand's largely-undeveloped marine jurisdiction, to benefit the New Zealand economy and society, consistent with the UN Convention on the Law of the Sea 1982	Sustainable exploration and extraction of seabed minerals – a theme within a broader theme or sub-challenge relating to realising the economic potential of New Zealand's ocean resources (e.g. petroleum, methane hydrates, electricity generation)
409	Accelerate development and extraction of wealth from New Zealand's marine resources, while maintaining the diverse range of ecosystem services that our vast oceanic region provides	1. Through Government, industry and community collaboration, discover the full extent of petroleum and mineral resources within our EEZ, and advance extraction methods that minimise and mitigate environmental impacts while maximising economic return 2. Expand and diversify the aquaculture industry into high value species and products, maximise the sustainable catch and value from our wild fisheries, and develop ecosystem based management approaches to increase economic returns from New Zealand seafood 3. Enable New Zealand to maintain the health of its marine ecosystems and associated resources through adapting to and mitigating the impacts of oceanic change 4. Management systems that allow multiple uses of oceanic, coastal and estuarine habitats,

Entry Id	Challenge	Themes
		incorporate environmental and human-derived stressors, and meet the needs of all stakeholders

Entry ID	88
To generate wealth from petroleum resources in the exclusive economic zone	
Summary	This challenge proposes to perform Seismic surveying of sediment basins within the Exclusive Economic Zone (EEZ) to determine the prospectivity of these areas, which could act to attract overseas investment in securing these resources. Harvesting of petroleum resource within the EEZ will involve the generation of new technologies and legislation to ensure that maximum benefit is derived at minimum cost. One of the main risks that need to be mitigated involves that effect of offshore oil mining on aspects of the environment.
Theme 1 **Understanding the prospectivity of the sedimentary basins in the EEZ**	
Importance to New Zealand	Determining prospectivity will affect the desirability of New Zealand as an investment destination - thereby attracting overseas explorers during blocks offer rounds. Scientists should work more closely with companies exploring offshore. The Government needs to provide more resources to interpret and disseminate the information that is collected.
Research components	Continuing seismic surveys in frontier basins to develop a better understanding of conventional petroleum resources available. Making money available to adopt overseas technology/software to better interpret data which is collected, and which has historically been collected. Investigate the scale of methane hydrate deposits
Theme 2 **Develop an agreed system for evidence based decision making to include in legislation**	
Importance to New Zealand	Decision making is often made in an adversarial environment, where there is little agreement on the decision making framework. This makes outcomes uncertain for all parties and reduces investor confidence. The new EEZ legislation is perceived by many to be satisfactory for no one.
Research components	Examine overseas examples of decision making where consistently good decisions and outcomes are assumed to have been made. Undertake New Zealand research on what acceptable decision making is required to deliver good outcomes here.
Theme 3 **Managing the risks to the environment from offshore oil development**	
Importance to New	To obtain and maintain a social license to operate requires that industry

Zealand	undertake operations in a manner where the public has confidence that what we are doing is low risk. While industry is confident that the regulatory approach is appropriate, arm's length research could usefully identify how well we perform, bench-marked against other jurisdictions. Some research could be focused on how the New Zealand regulatory regime assists in meeting the above goal. The benefits of getting our regulatory regime right are huge, particularly if we deliver a safe and efficient outcome. See Norway which has developed a $500 billion Euro sovereign wealth fund off the back of offshore oil development
Research components	Develop design standards and operating procedures to meet social needs for safe and resilient offshore operations
Research Gaps and Opportunities	Very little work done on methane hydrates. Offers enormous economic potential if they can be monetized. More work could be done developing broad scale geological models of sedimentary basins where surveys have already been undertaken. More money could be invested in database management and collections management of existing resources. Research could also focus on the following: Reservoir production geology to help maximise production of known reserves. This addresses "energy efficiency" (supply side) in the overall New Zealand energy context, and is again beneficial to industry as well as being aligned with Government aims. Estimation of the quantity of undiscovered petroleum resources, starting with the most prospective basins. This will be primarily of use to Crown Minerals, and Govt. energy policy makers. Digital database development and digital platforms for more effective technology transfer. Includes GIS-geospatially referenced data packages. This is of benefit to companies and Crown Minerals, and would be linked to their data delivery.

Entry ID	**147**
To explore the geology and geophysics of our offshore basins so we improve our knowledge of their resource potential and their tectonic history	
Summary	This challenge proposes to carry out basic geophysical research of our undersea sediment basins in order to convince exploration companies they are worthy of investment. Such research will involve seismic/tectonic surveys, and interpretation of pre-existing and newly generated geophysical datasets.
Theme 1 **Carry out geological exploration of our offshore territory**	
Importance to New Zealand	Our offshore regions also represent one of the last, large, continental areas to be explored for scientific reasons and are a potentially large resource base for New Zealand. One of the issues with getting companies interested in these frontier basins is the lack of existing scientific knowledge about their structure, geological history and thus thermal regimes. These are the crucial data to convince exploration companies that they are worthy

	of further investment. For example, the New Caledonian Basin (fig. 1) lies to the northwest of the North Island and sits behind the largest subduction system in the world; the Tonga-Kermadec subduction zone (fig.1). As the creation of a subduction zone is one of the main drivers of many basin types, research on plate tectonics for our part of the South Pacific will flow on to studies of basin initiation, basin thermal history and thus resources. Our offshore basins therefore represent an important strategic target for new research.
Research components	The research needed to address this theme is largely offshore geophysical data acquisition and interpretation. In the first instance there are huge geophysical data sets on our offshore areas, now held by the New Zealand Petroleum and Minerals (part of MBIE) , and that have come from the private oil companies. Interpretation of these data would be the start. The next step of research would be the acquisition of new seismic lines along regional transects. This type of data cannot be acquired by exploration companies as they are restricted to license areas. But it's the regional lines that give us the vital clues to unravel the geological history of a region.
Theme 2 **Carry out exploration of basins and structures close to land**	
Importance to New Zealand	Basins, faults and uplifted regions close to our land are vital not only for the exploration of resources but also for understanding and mitigating the effects of natural hazards. For example, recent offshore marine geophysics has helped to pin point tremor on the Alpine fault. Tremor is a form of slow, semi continuous slip on faults and may be responsible for "loading up" faults to the point of major failures. Hence, it's important to monitor tremor continuously. The seismic "onshore-offshore" method has been used to study and image our major seismic hazard regions: Wellington, Hawke Bay and the Alpine fault. This type of work shows where faults are getting "locked" and potentially hazardous.
Research components	Carrying out the onshore-offshore seismic method around the coast line of New Zealand. This method involved seismic receivers being deployed on land areas with a GPS timing base, recording air gun shots from ships working offshore. This can be done by collaboration between different groups. It can also involve the deployment of offshore "ocean Bottom Seismographs" or OBSs. At present we borrow or hire these from institutions in the US, Japan and Australia.
Research Gaps and Opportunities	There will be gaps in the sense that the present offshore exploration by the private oil companies does not extend into all our EEZ. We need to bring in collaboration with science funders from other countries. As it happens much of our EEZ is of vital interest to the international science community because it's bisected by the world's longest and oldest subduction zone - The Tonga-Kermadec system. We can, and have, exploited this setting to leverage international groups to work in our EEZ. For example in the last 10 years we have had ships or groups from the USA, Japan, the UK, Germany and France working in the EEZ. Another opportunity is the chance to get the International drill ship (Glomar

	Challenger) into our EEZ in 2015 as part of the International Ocean Drilling Programme (IODP) program me. There is a strong, New Zealand -led, proposal to drill the Lord Howe Rise for climate and tectonic research. If this happens about $50 million worth of stratigraphic drilling will be conducted in our territory at no cost to New Zealand tax payers. But for this to be successful we need to the show the IOPD that the New Zealand scientists involved have government support and funding.
Comments	It is vital that the Universities play a key role in this research. This is for reasons of capability building. The research involves high level geophysics and there is a global shortage of these people. Most geophysicists have the chance to work in high paying jobs anywhere in the world. We need to be training our own so we can maintain expertise in our country. This can only happen if the universities have top research programmes through which they can attract the best students.

Entry ID	**247**
Establishing a research and development project that explores the potential of South Island silica deposits	
Summary	The goal of this proposal is to make use of South Island silica deposits. There are many silicon based products such as sealants (silicones), abrasives, and metals of various purity (metallurgical, solar, electronic grade silicon metal). By understanding how New Zealand silica can be purified and processed through the value chain then opportunities open up for establishing competitive products starting at based-refined silicon. Also new products can be developed around the resource e.g. a low grade silicon sealant material that would replace bitumen as a road sealant.
Theme 1 **Establish the value of South Island silica deposits**	
Importance to New Zealand	Sustainable silica to silicon industry in New Zealand has the potential to provide many hundreds of green and clean tech jobs. Raw and added value for both existing and new silicon based products has the potential to bring very large export derived income to New Zealand.
Research components	Silicon products technology Silica purity technology Silicon refinery technology
Research Gaps and Opportunities	There are many silicon based products such as sealants (silicones), abrasives, and metals of various purity (metallurgical, solar, electronic grade silicon metal). By understanding how New Zealand silica can be purified and processed through the value chain then opportunities open up for establishing competitive products starting at based-refined silicon. Also new products can be developed around the resource e.g. a low grade silicon sealant material that would replace bitumen as a road sealant. Much of this challenge addresses the production of cost-effective materials that replace fossil carbon based products e.g. silicon for photovoltaic

	solar panels.
Comments	There has already been some research done on aspects of this project in collaboration with an off-shore technology company.

Entry ID	**307**
Wealth and Security from Geological Resources	
Summary	(1)Prospectivity to prosperity - greater exploration of our extensive Exclusive Economic Zone, including frontier offshore basins, and EEZ minerals, onshore minerals etc. (2) Security of supply – investigate enhanced geothermal use, unconventional petroleum sources, mineral technology opportunities, availability of aggregate supplies: Significant issues around the future availability of aggregate for infrastructure construction etc. (3) Stewardship – investigate responsible mineral and petroleum development, ways to mitigate the risks associated with hydraulic fracturing, deep sea drilling, and seismic surveys etc.
Theme 1 **Prospectivity to prosperity - facilitating greater exploration of our extensive Exclusive Economic Zone, so enhancing the discovery of new reserves of petroleum and minerals, leading to significant improvement in the New Zealand economy**	
Importance to New Zealand	Petroleum and minerals are currently among the country's highest export earners. Exploration injects around $1.5 billion a year into the economy and the Government receives over $2 billion a year in royalties, levies and corporate taxes from oil, gas and mining operations. While significant, the income could be much higher. New Zealand has jurisdiction over the fourth largest EEZ and ECS in the world, an area of 5.6 million km^2. This vast area has potential to provide wealth from petroleum and mineral extraction for many generations to come. Exploration activity and success in such frontier areas depends on the availability of good technical information. The main barrier to realising our full geo-resource potential is the lack of detailed knowledge of the structure and characteristics of the 17 frontier sedimentary basins that surround New Zealand, and the value of seabed minerals found along the volcanic arcs to the north and in the deep sea to the northwest and southeast. As there has been only limited mineral exploration onshore, significant potential remains for extraction of precious and base metals. Increased provision of high-quality data and improved understanding of our potential geo-resource endowment through scientific research will help the Government to promote New Zealand as a desirable destination for exploration investment, and to optimise value from licensing and industry activity. Increased activity will lead to discoveries, bringing new revenue flows and a host of spin-off economic benefits nationally and locally.

Research components	1. Frontier offshore basins, and associated petroleum system analysis: The petroleum systems of our frontier basins need to be studied in more detail, both to quantify the resource potential and to attract investment and activity by petroleum exploration companies. The fundamentals of basin structure and evolution need to be complemented by an understanding of the distribution and characteristics of source and reservoir rocks and a semi-quantitative evaluation of petroleum generation, migration and trapping, in order to delineate the most prospective areas for exploration. 2. EEZ minerals: Enhanced knowledge of the origins and extent of alluvial minerals, seafloor massive sulphides, ferromanganese nodules and crusts, and gas hydrates is needed to spur interest by offshore mineral exploration companies, especially in currently unexplored regions such as the Havre Trough and Colville Ridge to the north of New Zealand. 3. Onshore minerals: Enhanced prospectivity of on-land precious metals, particularly gold, silver and platinum group is needed to expand and broaden mining activities and increase the current revenue stream for the government.
Theme 2 **Security of supply – ensuring New Zealand is resilient to global restrictions on the availability of strategic energy and minerals resources**	
Importance to New Zealand	New Zealand is a small country, distant from all hubs of global activity. We are vulnerable to erratic supply or price fluctuations of essential commodities, particularly petroleum and strategic metals. The best way to buffer against this is to establish an indigenous supply of strategic resources, both in terms of volume and variety. Currently, our utilisation of geothermal energy, particularly in terms of the deep and shallow resource is less than optimal, and we have yet to fully explore the potential of unconventional petroleum resources such as coal-seam gas, shale gas and gas hydrates. Realising the full potential of industrial minerals such as clays, zeolites, building stone etc. will have benefits both in terms of import substitution (reducing overseas debt) and developing local industries. Both geothermal and industrial mineral developments are of particular interest to Māori, who have governance over many of the richest resources. Supply of strategic metals such as copper and nickel is becoming more critical globally as the demands from ‘green energy’ technologies (wind turbines, batteries, solar panels etc.) outstrip production + recycling. An indigenous supply of such metals will buffer the country against shortages and price hikes that will inevitably become commonplace in the future. Availability of aggregates for construction is another key reliance issue that has received scant attention to date. Secure supplies of groundwater are also vital to underpin our biological and manufacturing industries, and will be even more so in the future as surface supplies become increasingly in demand for domestic use.
Research components	1. Enhancing geothermal use: The extremely high heat flow in central North Island has provided New Zealand with a rare endowment of geothermal energy, which is

	currently under-utilised. By tapping deeper sources, and better utilising low-temperature resources, a doubling of current electricity generation is considered possible. Further research is critical to exploring both these possibilities. 2. Investigating unconventional petroleum sources: Enhanced research into the potential of coal-seam gas, shale gas and methane gas hydrates is needed to establish their future viability. 3. Realising mineral technology opportunities: Processing of New Zealand's diverse and abundant supplies of industrial minerals (clays, zeolites etc.) is required to fully develop their potential as import substitutes, and as the basis for new or enhanced local industries. 4. Ensuring the availability of aggregate supplies: Significant issues around the future availability of aggregate for infrastructure construction (i.e., closure of inner-city and riverine sources) need to be urgently addressed. 5. Determining the availability of strategic metals: New Zealand has some potential for strategic metals, including rare earth elements, which has yet to be fully investigated. 6. Maximising groundwater availability: Although the locations of our major groundwater aquifers are known, there is still a great deal to learn about their detailed plumbing systems.
Theme 3 **Stewardship – minimising environmental impact whilst realising the full benefits of our natural endowment of geothermal energy, petroleum, mineral and groundwater resources**	
Importance to New Zealand	In a competitive world it is in New Zealand's best interest to take advantage of our natural resources with which our nation is well endowed. However, a compromise is required to allow us to use our inventory of geo-resources while preserving the integrity of our other natural assets. New Zealanders have great respect for their natural environment, and the ecosystems that exist within it. In realising the benefits that will arise from increased geo-energy, mineral and groundwater extraction, it is imperative that the impacts on the natural environment are minimised (recognising that there will always be some impacts from such activities). In permitting extraction activities, the Government, guided by expert advice, must weigh up the positive impacts (export revenue, jobs, and security) against the negative impacts (impacts on biodiversity, ecosystems, landscapes and the atmosphere). It is vital to understand the true magnitude of the impacts and find ways to mitigate them. Such information is critical if the Government is to develop sound, evidence-based policies and regulations around mining activity, and the industry is to be equipped with appropriate knowledge and tools to deal with regulations, and any issues that may arise. This theme addresses specific side effects of developing key resources, and utilises similar research capability and specialist expertise to that required to delineate the resources.
Research components	1. Responsible petroleum development: Investigating ways to mitigate the risks associated with hydraulic fracturing, deep sea drilling, and seismic surveys

	2. Responsible mineral development: Investigating ways to mitigate the risks associated with acid mine drainage, marine sediment plumes, and disturbance of marine ecosystems 3. Sustainable geothermal development: Investigating ways to mitigate the risks associated with geothermal development, including ground subsidence, reduction of thermal features, reduced biodiversity, and pollution of waterways 4. Balancing the carbon budget: Developing options for carbon sequestration, particularly for enabling the use of giant gas fields with >10% natural CO_2 5. Improving groundwater quality: Investigating the cause and effect of groundwater contamination, and developing appropriate mitigation strategies
Research Gaps and Opportunities	The following initiatives would significantly boost all three goals of this challenge – increasing New Zealand's prosperity, enhancing security of supply, and improving responsible management and public acceptability of extraction operations. 1. More ship-time to explore frontiers and for ecological baseline research: This is a 'big ticket' item, requiring several $million additional each year due to the high cost of research vessels [removed due to commercial sensitivity]. Our vast EEZ will take many decades to fully explore, but an intensive, targeted effort in the near-term would pay substantial dividends. 2. Enhanced data management: This is a key component for the Government to promote exploration activity. 3. Regional geochemical and geophysical mapping: This is critical for prospectivity assessment on land and near-shore, and has spin-off benefits in agriculture, forestry and regional health. 4. Re-establishment of mineral processing research capability: This is necessary for the development of new mineral technologies. 5. Establishment of a virtual centre (hub) for geo-resources research: This would help to coordinate research activities, which are currently carried out by several different agencies. It would also enhance interaction with consultancies and industry. 6. Research into carbon sequestration: Technically similar to petroleum research, this currently receives little funding, inhibiting development of future gas fields and associated regional industry. 7. Research into unconventional petroleum, aggregates and mineral technology opportunities: These all represent opportunities that are largely un-researched at present. 8. Development of advanced technologies: This is necessary to effectively explore our territory and assess our resources.
Comments	Much of New Zealand's past wealth has been generated from physical resources that lie on or beneath the land's surface or seabed – so-called geo-resources. There is vast potential for even more such wealth generation. For instance,

	extrapolation of geological understanding of Taranaki Basin, now a significant oil and gas producer, to other basins around New Zealand suggests that, in time, commercial petroleum discoveries there are highly likely. With increased revenues from geo-resources, the Government could ease current fiscal constraints and invest more on social programmes (health, welfare, policing, retirement) and in future-proofing the nation via R&D and education, thus enhancing the well-being of all New Zealanders. This challenge is deliberately focused on geological resources to ensure that the research community can address key strategic issues in a coherent way, without being diverted by other essentially disconnected (though important) concerns. If other 'natural resources' such as soils, fisheries, and forests were included, established research interconnections, which are well suited to addressing the stated goal may be weakened. The over-arching tenet is to optimise the use of our geo-resources endowment in a systematic, planned way, gathering as much salient technical data as possible, to make well-informed decisions on optimising the exploration and development process. A parallel tenet is that geo-resources can be developed without undue environmental harm. Potential research collaborators include universities (Victoria, Auckland, Otago, Waikato, Canterbury, Massey, Lincoln), NIWA, ESR, Landcare and CRL. The general thrust of the challenge is supported by mineral industry associations Straterra and NZMIA.

Entry ID	**328**
Turbocharging New Zealand's economic growth and future-proofing our economic resilience and global competitiveness by bringing forward the managed exploration and development of oil and gas resources within our vast Exclusive Economic Zone	
Summary	This challenge proposes to perform basic geophysical research of our undersea basins in order to convince exploration companies they are worthy of investment. Such research will involve seismic/tectonic surveys, and interpretation of pre-existing and newly generated geophysical datasets- Beginning at Taranaki (our premier basin for exploration), such research can then be applied to novel sediment basins to reveal their petroleum prospectivity. This research can also focus on environmental sustainability/climate change by looking at non-conventional sources of petroleum (such as shale gas/oil, coal seam gas etc.).
Theme 1 **Understand, map and communicate the petroleum prospectivity of New Zealand's basins, thereby reducing subsurface technical risk and geological uncertainty, leading to accelerated exploration activity and new oil and gas discoveries**	
Importance to New Zealand	Optimising New Zealand's advantage through accelerated discovery and development of our endowment of oil and gas could transform our economy and the well-being of all New Zealanders. Petroleum imports at around $6.5B per year

	are a major drain on our economy, yet oil is also our 4th largest export earner. With one or two large discoveries, we could become a net exporter of oil or LNG. Oil and gas exploration already injects $1.2 billion per year into the economy and contributes a further $700 million each year to Government through taxes and royalties. With higher revenues, the Government could spend more on social programmes; environmental and conservation management; and education, research and development. Other positive outcomes of local petroleum discoveries will be greater opportunities for regional development and employment; more robust transport, industrial and infrastructure sectors; and enhanced national energy security. New Zealand's EEZ is the 4th largest in the world and provides a massive opportunity for wealth creation. Our most economically important petroleum-bearing rocks lie hidden beneath the Taranaki sea bed, and these are not yet fully understood. It is a major challenge to identify and substantiate the petroleum potential of the rest of our vast, largely unexplored, offshore territory.
Research components	1. Understanding New Zealand's petroleum systems, including the origins and properties of their petroleum fluids: New Zealand's petroleum systems have been fashioned by our particular geological history, such that local and overseas exploration companies rely heavily on data and knowledge generated by New Zealand research. Examples include predictions of the volumes and types of petroleum expelled by different source rocks, understanding the impact of faults on the migration of oil, and mapping the stratigraphic architecture of New Zealand's basins to predict reservoir distribution. 2. Mapping and modelling the remaining petroleum prospectivity of Taranaki Basin: Taranaki is our premier basin for exploration, but making new discoveries is increasingly challenging: the easy barrels have been found already. Continued success requires the development of new geological insights and predictive tools. This research component will utilise modern exploration data and samples to create state-of-the-art 4D (3D geological volume + geological time) models to predict the volumes and timing of oil and gas generation; migration pathways; and the locations of petroleum accumulations throughout Taranaki Basin. Many of the concepts developed for Taranaki can also be applied in our frontier basins. 3. Investigating the structure, sedimentary fill, geological history, and petroleum prospectivity of New Zealand's frontier basins: New Zealand has 17 under-explored frontier basins, some with proven but poorly understood petroleum potential. This component will undertake fundamental geophysical, geological, and geochemical studies of our offshore basins, and will develop maps of petroleum systems elements to identify areas with good petroleum prospectivity.
Theme 2 **Overcoming barriers to, and managing risks associated with, the development of New Zealand's petroleum resources, to enable generation of new wealth for New Zealand in a socially and environmentally acceptable manner**	
Importance to New Zealand	New Zealand is a small country, distant from global centres of activity. Consequently, we are vulnerable to commodity supply and price fluctuations,

	particularly for oil. We can buffer this by expanding and diversifying our indigenous sources of petroleum. Unlocking unconventional oil and gas resources, such as shale gas and oil, coal seam gas, and gas hydrates, will help in not only diversifying our primary energy supply, but in providing jobs and investment in regional centres. We are only beginning to explore our unconventional resources, and our knowledge of these is even less than that of our conventional petroleum resources. New Zealanders have great respect for their natural environment, so it is imperative that in realising the many benefits from increased oil and gas extraction, any potential impacts on the natural environment are minimised and properly managed. Complementary research addressing New Zealand-specific environmental aspects, such as carbon geo-sequestration and fracking, should accompany prospectivity research. Concerns about atmospheric emissions from burning fossil fuels compete with the pragmatic reasons for expanding and diversifying our gas supply. However, gas use is not without some environmental benefit. Gas is a cleaner fuel than coal for electricity generation and globally is becoming the transition fuel of choice en route to a renewable clean energy future. Whilst New Zealand is already a world leader in this regard, new gas discoveries here will continue to provide generation back-up as we wait for both technological advances and public acceptance of renewable electricity alternatives.
Research components	1. Determining the distributions and critical properties for development of New Zealand's unconventional petroleum resources, including shale gas and oil, coal seam gas, and gas hydrates: Shale and coal seam gas are revolutionising global supplies of gas. New Zealand has significant potential for development of shale gas and oil (e.g. East Coast Basin), coal seam gas (Waikato, Taranaki, Southland), and gas hydrates (offshore East Coast and Fiordland). There remains, however, a lack of the necessary research to help encourage and support the commercial development of these resources. Research is required, for example, to assess the distribution and quality of potential reservoirs, and to evaluate critical parameters for gas production. 2. Investigating ways to reduce and ameliorate the potential environmental impacts associated with the extraction of conventional and unconventional petroleum resources: The advent of hydraulic fracturing to unlock unconventional gas resources has created an urgent need to assess and minimise potential environmental impacts associated with its use, including potential contamination of groundwater aquifers, disposal of fracture fluids and subsurface waters, and the prudent use of water resources. 3. Investigating the storage potential and environmental impacts of geo-sequestration of carbon dioxide in saline reservoir rocks deep underground in disused oil and gas fields: Much research is required before large-scale sequestration of carbon dioxide is undertaken in New Zealand, from operational, environmental, and safety standpoints. This includes research on CO_2 seal rock properties and potential column heights; the nature of CO_2-rock reactions for different reservoir lithology's; and seismic risk assessments.

Research Gaps and Opportunities	The following initiatives are suggested to help achieve this challenge: 1. Establishment of a national Petroleum Research Centre: This would be a (semi-virtual) hub designed to better coordinate government-funded research activities; provide a more effective interface with exploration companies and other stakeholders (including the public); and bolster capability development and technical capacity through student training and industry workshops. Technical capacity in particular is a major concern going forward. The idea of a Petroleum Research Centre previously received good support from key participants, but stalled for lack of funding. 2. More ship-time to explore frontiers and gather ecological baseline data: This is a 'big ticket' item requiring several $M additional each year due to the expense of research vessel time [removed due to commercial sensitivity]. Our vast EEZ will take many decades to fully explore, but an intensive, targeted effort in the near-term would pay substantial dividends. 3. Enhanced accessibility of data and knowledge via the web: Global access to high quality information on basin prospectivity is critical for promoting New Zealand exploration and, ultimately, improving the strike-rate of new discoveries. 4. Research into unconventional petroleum resources: These resources represent a tremendous opportunity in both the short- and long-term, but the necessary research to enable their profitable, safe and environmentally sound commercialisation under New Zealand conditions is currently lacking. 5. Increased research into carbon sequestration: This is technically similar to petroleum research, but is currently underfunded inhibiting our ability to mitigate the effects of development of future gas fields and associated regional industry.
Comments	The challenge as described above is deliberately focused on petroleum, because, of our natural resources, it has the greatest revenue-generating potential. Norway, a country of similar size and aspect to New Zealand, was transformed from subsistence to a wealthy nation in a matter of years by one or two major oil or gas discoveries: the same could happen to New Zealand. The small Tui oil-field contributed 3% of our GDP during its production heyday. In the Gippsland Basin, with similar petroleum source rocks to ours, the Kingfish Field is roughly 40 times larger than Tui. Current Government funding for dedicated petroleum research is small (c. $5 million pa) when compared to the present and potential future value of indigenous oil and gas reserves to the New Zealand economy. Better understanding of our petroleum-bearing basins would provide Government with an improved basis to promote exploration and maximise returns from licensing, whilst also giving companies more confidence in their exploration decisions. The results of research into carbon geo-sequestration and fracking will help inform Government policies and regulations around petroleum extraction, as well as best practice procedures for industry. Contributors to the challenge may include GNS Science, universities (Victoria, Auckland, Otago, Waikato), NIWA, CRL, PEPANZ, NZP&M and CO_2CRC.

<table>
<tr><th>Entry ID</th><th>335</th></tr>
<tr><td colspan="2">The Challenge is that New Zealand's past economic performance has been poor. The goal of this challenge is to develop larger and more diversified export income sources to make the New Zealand economy more resilient and prosperous</td></tr>
<tr><td>Summary</td><td>The goal of this proposal is to increase New Zealand's economic performance by using New Zealand's land and marine mineral resources. The proposed research programme includes the following themes:

(1) develop technologies to enable extraction of petroleum, minerals and materials with novel properties from our marine, undersea and underground resources in an environmentally responsible manner - better characterise New Zealand's geological structure and seabed to identify areas of high potential to attract international petroleum companies and encourage further exploration via drilling programmes

(2) use leading edge information and communication technologies to embed unique functionality in a range of products, processes and services - develop a leading edge technology platform and associated expertise to develop a diverse range of world leading applications and products

(3) advance multidisciplinary product development methodologies drawing on design, engineering, technology and science expertise - develop products with increased performance and value

(4) create novel materials and processes from which to build transformative technology platforms that disrupt markets, are less hazardous, or render obsolete products made by others - development of a technology platform which enables materials to be developed, tested and characterised before being used in products etc.</td></tr>
<tr><td colspan="2">Theme 1

To develop technologies to enable extraction of petroleum, minerals and materials with novel properties from our marine, undersea and underground resources in an environmentally responsible manner</td></tr>
<tr><td>Importance to New Zealand</td><td>Based on analysis by BERL and NZIER the potential economic outcomes from plausible oil and gas discovery and from development scenarios, exports could grow by $1.5 billion per annum, royalty payments increase by $320 million per annum, and a further 5,500 jobs could be created. The analysis suggests that with direct and in-direct effects, national GDP could increase on average by $2.1 billion for each year of a 30-year development of a new basin.

Information is the key to attracting exploration companies to New Zealand and realising these economic benefits and an improved geo-science database will enable petroleum and mineral resources to be evaluated, assessed and accessed. In addition to oil and gas, development of materials with novel properties is needed. The ability to extract these materials will broaden the range of materials</td></tr>
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	available to New Zealand to use, utilise in manufacture and export. Such diversification will open new markets and provide New Zealand with new opportunities to expand its economy.
Research components	Research is needed to better characterise New Zealand's geological structure, particularly for the 17 known frontier sedimentary basins as hosts for gas or oil. This data will enable identification areas of high potential which will attract international petroleum companies and encourage further exploration via drilling programmes. Research is needed to better characterise New Zealand's seabed. Resource potential has been identified for seabed base and precious metals (Kermadecs), rock phosphate (Chatham Rise), and iron-sands (seas off the western North Island). Enhanced knowledge of the origins and extent of alluvial minerals, seafloor massive sulphides, and ferromanganese nodules and crusts, is needed to spur interest in offshore mineral exploration, especially in currently unexplored regions such as the Havre trough and Colville Ridge to the north of New Zealand. On-going research by Crown Research Institutes is required on hydrocarbons in general and in relation to gas hydrates in particular. The development of a comprehensive hydrates information repository, as recommended by the Centre for Advanced Engineering New Zealand, is also needed. Such a repository is essential for the future investigation and evaluation of the hydrates opportunities in the sea bed.
Theme 2 **The goal is to use leading edge information and communication technologies to embed unique functionality in a range of products, processes and services**	
Importance to New Zealand	Embedding unique functionality will result in new and innovative products, processes and services which will open up new markets or deepen existing markets. This will provide New Zealand with opportunities to be a market leader and diversify its economy, making it more resilience to changes in other markets.
Research components	Development of a leading edge technology platform, with development of associated expertise, is required to develop a diverse range of world leading applications and products.
Theme 3 **The goal is to advance multidisciplinary product development methodologies drawing on design, engineering, technology and science expertise**	
Importance to New Zealand	The advancement of multidisciplinary product development methodologies will result in products and services that are more dynamic and more robust than those developed without multi-disciplinary approaches. Multi-disciplinary approaches will ensure joined-up thinking and diversity in development, resulting in innovation and the ability to better understand how technical, social and scientific aspects fit together.
Research components	Research is needed to develop products with increased performance and value. Development of these products relies on knowledge know-how and an appreciation of markets and users.

Theme 4 The goal is to create novel materials and processes from which to build transformative technology platforms that disrupt markets, are less hazardous, or render obsolete products made by others	
Importance to New Zealand	The use of transformative technology platforms using novel materials and processes will enable the creation of new markets for products and services from New Zealand, thereby diversifying the economy. In addition the products and services may be less hazardous than similar existing products and services, making them more desirable than their competitors and reducing environmental risks associated with them. This will benefit the New Zealand economy, the environment and all those who interact with the products and services. It will also cause spin-off benefits such as improving the profile of New Zealand's manufacturing sector and the profile of New Zealand's environment, providing the country with further benefits.
Research components	Research components for this theme include the development of a technology platform which enables materials to be developed, tested and characterised before being used in products which will be world-leading. Research is also needed to investigate materials that are more advanced than convention materials. For example, research could investigate smart materials that could be used in areas of stress due to heat, temperature change, mechanical stress or changes in light.
Research Gaps and Opportunities	Theme 1 Gaps and opportunities New Zealand has the fourth largest Exclusive Economic Zone – 96 per cent of which is underwater and only 13 per cent of which has been mapped in any detail, the potential to improve our knowledge of and information on our petroleum resources is enormous. It is noted by GNS Science that there is no inventory map or comprehensive compilation of undrilled prospects in New Zealand. There is much yet to know regarding the petroleum prospectivity of the sub-seafloor of the 17 sedimentary basins that comprise 30% of the zone, before they can become primary targets for exploration and, ultimately, petroleum extraction. Similarly, the extensive seafloor mineral deposits must be better mapped and their formation understood before further exploration can take place.

Entry ID	**378**
Environmentally-responsible intensification of land and water-use, in relation to New Zealand primary industries , to benefit the economy and society	
Summary	Increased minerals exploration for the purpose of making comprehensive, pre-competitive information, regarding minerals prospectivity and resource potential, available to investors and improving New Zealand's attractiveness for investment

Theme 1 Increased minerals exploration and development on land, via improving New Zealand’s attractiveness for investment	
Importance to New Zealand	New Zealand is prospective for gold + silver, coal, ironsands, aggregates, and industrial minerals (e.g. limestone, clays), among other mineral resources, such as platinum group elements, tungsten, and rare earth elements. Minerals have been identified for their potential to contribute to New Zealand’s economic growth in the Government’s economic growth agenda. With around 15,000 New Zealanders currently employed directly and indirectly in the minerals and oil & gas sectors, that figure could double or treble over time. As global minerals scarcity increases, the likelihood of this scenario increases. Better knowledge of New Zealand’s aggregate resources would provide for better planning of land use, to avoid the unnecessary and costly “sterilisation” of aggregate resources, from incompatible land uses, and reverse sensitivity over land uses. For instance, if Christchurch were to expand so as to sterilise nearby aggregate resources, the extra cost to the city to source that aggregate from elsewhere could reach $500 million, according to the Association of Quarries and Aggregates.
Research components	Minerals exploration is high-risk. Its purpose is to increase knowledge about New Zealand’s minerals prospectivity and resource potential. It depends on investors, usually overseas investors, who are prepared to take the risk. New Zealand’s attractiveness for that investment depends, among other factors, on regulatory stability, access to resources, and prospectivity and resource potential. It is much easier to attract investment if comprehensive, pre-competitive information is available. In 2010 GNS Science developed a $70 million, 5-year proposal for a nationwide aeromagnetic and geochemical survey of mineral prospectivity. Such a survey could be broadened to include other objectives, such as assessment of groundwater resources, natural hazards, agriculture, and health. In the event, Northland was surveyed for minerals, and Westland is currently being surveyed. The expected payback is significant. For every public dollar invested in exploration data in 1987-1996 in Australia, $A360 is earned in mineral exports, $A15 is earned in the export of services, and $A11 is returned to the government as taxes and royalties. Canada’s Targeted Geoscience Initiative has found that every public dollar spent in Canada has led to $C5 in private sector investment and $C125 in discovered resources. Relevant research providers include GNS Science, Universities of Otago and Auckland, CRL Energy.

Entry ID	379
Environmentally-responsible identification of and development of resources within New Zealand's largely-undeveloped marine jurisdiction, to benefit the New Zealand economy and society, consistent with the UN Convention on the Law of the Sea 1982	
Summary	This challenge proposes to carry out environmentally-responsible preliminary exploration to determine the abundance/occurrence of seabed-mineral resources within New Zealand's largely-undeveloped EEZ. Research will include predictive modelling of resource abundance/occurrence, and investigating the potential environmental effects of explorative work (and future extraction of minerals).
Theme 1 **Sustainable exploration and extraction of seabed minerals – a theme within a broader theme or sub-challenge relating to realising the economic potential of New Zealand's ocean resources (e.g. petroleum, methane hydrates, electricity generation)**	
Importance to New Zealand	Resource potential has been identified for seabed base and precious metals (Kermadecs), rock phosphate (Chatham Rise), ironsands (seas off the western North Island), and extensive ferromanganese deposits (off the Campbell Plateau). Even if only a fraction of the above resources were developed, economic activity could result of more than $1-2 billion a year, including in taxes and royalties, and providing hundreds if not more than 1000 new jobs, according to prospecting, exploration and research interests such as Trans-Tasman Resources, Chatham Rock Phosphate, Neptune Minerals, and Nautilus Minerals.
Research components	The work to identify and prove up economically-recoverable resources is in the early stages, yet the potential is enormous, as noted above. That could include baseline studies, and predictive modelling of resource occurrence. That said, there are generic issues to do with understanding the environmental effects of seabed minerals activities, and how those effects could be managed to the standards required in New Zealand legislation. These issues are significant, and will also require, in many cases, the innovation of existing technologies, and the development of new technologies. Raising the capital to invest in the above poses a challenge related to the level of risk, against expected reward. There is a role for publicly-funded science to add to the store of knowledge in this area, and thereby reduce the level of risk faced by private investors when considering the exploration of opportunities in minerals in New Zealand's marine jurisdiction, weighed against the level of risk and opportunity posed in other parts of the world. Relevant institutions include in no particular order: GNS Science, NIWA, Cawthron Institute, and universities with marine environmental and minerals research capabilities.

Entry ID	409
Accelerate development and extraction of wealth from New Zealand's marine resources, while maintaining the diverse range of ecosystem services that our vast oceanic region provides	
Summary	This challenge proposes to develop methods for extracting maximum value from the EEZ whilst minimising environmental/ecological impact. This will involve preliminary explorations to generate quality data on petroleum prospectivity, mapping of sediment basins/seafloors to determine mineral content, and using measurement tools and predictive models to assess the environmental impacts of extraction activities (deep-sea drilling, mining, fracking). Fisheries management strategies also need to be developed to ensure the sustainable, profitable, and environmentally friendly harvesting of the various valuable marine species.
Theme 1 **Through Government, industry and community collaboration, discover the full extent of petroleum and mineral resources within our EEZ, and advance extraction methods that minimise and mitigate environmental impacts while maximising economic return**	
Importance to New Zealand	In 2009, the United Nations Law of the Sea (UNCLOS) confirmed New Zealand's jurisdiction over an area of 5.6 million km^2 of Exclusive Economic Zone (EEZ) and Extended Continental Shelf (ECS), the fifth largest marine territory in the world. It is estimated that this region contains many billions of dollars of petroleum and mineral resources, most of which is largely unexplored and yet to be quantified. For this endowment to be accessed for the benefit of all New Zealanders there is a need to provide critical resource data to attract prospective explorers, as well as providing information to Government to allow them to make sound management decisions and enact effective regulatory policy. There is much still to know regarding the petroleum prospectivity of the sedimentary basins that comprise 30% of the zone, before they can become targets for exploration and, ultimately, petroleum extraction. Similarly, the extensive seafloor mineral deposits must be better mapped and their modes of formation better understood to reduce exploration risk. Commensurate with these investigations, there is an obligation to acquire baseline knowledge and develop predictive models to assess the potential ecological and environmental impact of any extractive process being considered. Research that provides useful information for the management of risks associated with deep-sea drilling, and the fragility of marine ecosystems, is a necessary precursor to the awarding of mining licenses and the gaining of public approval. Development of techniques and methods to minimise or mitigate the environmental impacts of extraction may also be needed
Research components	1. Oil & gas (including gas hydrates): More and better quality data is needed on the petroleum prospectivity of our seventeen frontier sedimentary basins, to attract international petroleum companies and encourage exploration and drilling programmes. Evidence from the Taranaki Basin, now a significant oil and gas

	producer, indicates that enhanced exploration activity in other prospective basins is highly likely to yield positive results in the medium term (at c. $2.2 billion pa, petroleum is currently among the country's highest export earners). 2. Seafloor minerals: Enhanced knowledge of the origins and extent of alluvial minerals, seafloor massive sulphides, iron sands, phosphorites and ferromanganese nodules and crusts, is needed to spur exploration interest by mineral exploration companies, especially in currently unexplored regions, such as the Havre trough and Colville Ridge to the north of New Zealand. 3. Environmental impact: Measurement tools and predictive models are needed to assess how mining and other seabed activities will impact oceanic ecosystems and other resource users, and to assess the risks associated with extraction operations (e.g. deep-sea drilling, hydraulic fracturing, and natural hazards).
Theme 2 **Expand and diversify the aquaculture industry into high value species and products, maximise the sustainable catch and value from our wild fisheries, and develop ecosystem based management approaches to increase economic returns from New Zealand seafood**	
Importance to New Zealand	Our EEZ has 16 times the primary production of our land, and provides enormous opportunity to meet the growing global demand for seafood (over three billion people depend on seafood as a protein source). The wild fish catch has peaked yet the number of wild fisheries over-exploited continues to increase. Global aquaculture has grown 260% since 1992, and now produces the equivalent of half the global fish catch. There is a need, however, to ensure that improved seafood sector productivity and product attributes will meet the growing consumer demand for environmentally sustainable produce. Intensive aquaculture development has resulted in coastal environmental degradation in many countries and excess use of antibiotics for disease control. New Zealand's extensive clean coastal waters and internationally accepted fisheries quota management system provides a basis for significant growth in our seafood production in response to this global market situation. To realise this opportunity New Zealand will need to expand and diversify the aquaculture industry, through adding value to existing species and introducing new high-value species, explore and develop under-utilised wild fisheries, and increase certainty and confidence in fish stock management. Marine farming and wild fish catching techniques need to be developed that maximise product quality and minimise environmental impacts, especially damage to seafloor communities and unwanted by catch. Management of our aquaculture and fisheries needs to incorporate an ecosystem based approach if our seafood products are to meet international certification requirements and consumer preferences, and therefore command high value.
Research components	1. Wild fisheries Management: Improved knowledge of the biology and populations of key fishery species is needed to better inform annual quota levels and in so doing meet product certification requirements for sustainability. Also, the potential to increase harvest of under-utilised species needs to be determined. 2. New aquaculture products and species: There is a need to develop and

	advance commercial production of high value species and products. This includes the development of new farming technology, managing environmental risks, trait selection through selective breeding, and development of tertiary aquaculture products. 3. Environmental impact: Measurement tools, predictive models, new management approaches and industry guidelines are needed to quantify, minimise and mitigate the environmental effects (e.g. water quality, nutrification, seafloor damage, unwanted by catch, marine food chain changes) of aquaculture and fisheries activities. Research will ensure that the sector is able to meet consumer demand for seafood of verifiable quality and ecosystem sustainability attributes. 4. Ecosystem management approaches. There is a need to develop new models and tools that show how ecosystems and seafood production interact to enable prediction of future productivity and enable an ecosystem based approach to development and management of the seafood sector.
Theme 3 **Enable New Zealand to maintain the health of its marine ecosystems and associated resources through adapting to and mitigating the impacts of oceanic change**	
Importance to New Zealand	New Zealand is dependent on and derives a wide range of ecosystem services from its marine environment. A range of existing and potential new industries depend on these services (e.g. fisheries, aquaculture, tourism and energy). The oceans influence our climate, support infrastructure, have cultural significance and are an important recreational resource. The health of the oceans has global significance, especially the Southern Ocean, as it drives the world's climate system, has a major influence on atmospheric composition (through the absorption or release of gases such as greenhouse gases and oxygen) and mediates the earth's temperature. The oceans are undergoing change, however, in response to climate change, rising atmospheric CO_2 levels, pollution, land-use change and intensification, and overfishing. As a result the health of coastal regions has deteriorated, the oceans are acidifying at an unprecedented rate, sea-level rise is accelerating, major currents are changing, the oceans are warming and levels of primary productivity in some regions have changed. Predicting the impacts of these changes on the marine environment will be essential if we are to grow economic benefit from our ocean resources sustainably, especially fisheries and aquaculture. Research will underpin development of mitigation and adaptation measures required to optimise the health of coastal and oceanic ecosystems and the management of associated natural resources. Determining the impacts of global changes in the oceans is also of international concern, and research associated in this area of science plays a key role in New Zealand's science diplomacy with many of our key trading partners
Research components	1. Measurement: Monitoring of the changes in coastal and oceanic regions around New Zealand and the Ross Dependency is needed to inform management response to ocean change. Data from this region is key to international efforts to

	monitor and predict changes in the global ocean, and assists New Zealand's participation in international decision making associated with ocean governance. 2. Prediction: Development of predictive models of the multiple stressors (e.g. sea surface dynamics, current changes, acidification, coastal runoff) affecting our oceans is needed to forecast its future health and changes to marine resources (e.g. fisheries, biodiversity, bio-invasions). 3. Resource management: Development of methods and tools, based on ocean monitoring and forecasts, is needed to inform marine resource use and management. Such development will also assist New Zealand's contribution to international ocean governance.
Theme 4 **Management systems that allow multiple uses of oceanic, coastal and estuarine habitats, incorporate environmental and human-derived stressors, and meet the needs of all stakeholders**	
Importance to New Zealand	New Zealand's oceanic and coastal ecosystems contain customary, recreational and commercial fisheries; energy, mineral, water and petroleum resources; unique biota and areas with World Heritage status; ports, cables and pipelines; many opportunities for recreation and tourism, and spiritual significance; and a rich biodiversity that delivers numerous ecosystem services. Use of our marine environment and its resources, and conflict between users, has significantly increased in recent times. As a result, policy makers and resource managers face difficult decisions: how can industries work within the environmental capacity of our marine ecosystems but not be needlessly hindered in their development?; how do we ensure that critical ecosystem services (the value of which is estimated to be twice GDP) and heritage species are protected?; how do we ensure that the spiritual values and enjoyment of society, including iwi, are not impaired?; how do we retain our green image by not degrading our marine environment?; how do we capture and accommodate the diverse range of values of all existing and potential users?; and how do we do all this in an environment subject to constant natural change?. A combination of ecological and social science is needed to provide an inclusive and transparent framework that facilitates economic growth, improves marine stewardship and ensures that cumulative stresses placed on the environment do not degrade the ecosystem beyond its capacity to adapt.
Research components	1. Connecting ecosystems: A whole system approach is needed whereby all ecosystems (land to coast, river to estuary, seabed to water column, coast to deep sea) are appropriately understood and connected. Particularly important but poorly understood are the effects of land-derived inputs (sediment runoff, storm water, pollution) on marine ecosystem function. 2. Marine ecosystems resilience: Measurement and development of predictive models is needed to determine the resilience of marine ecosystems to the impacts of human activities, invasive species and global change. This is an essential prerequisite to developing tools to mitigate the impacts and enhance stewardship of our seas.

	3. Stakeholder values: There is a need to identify the aspirations of all users of marine waters (including iwi) in relation to recreational, food and commercial uses and to incorporate their differing perspectives of sustainability in a scientifically rigorous way into planning and management frameworks. Mechanisms for involvement of all stakeholders, rather than a sectarian approach, in defining acceptable limits of ecological sustainability is necessary to reduce conflict and enhances buy-in to management decision making. 4. Management frameworks and models: New management frameworks and interactive models to inform policy and management decision-making need to be developed, which incorporate multiples uses and impacts, ecosystem resilience, and stakeholder values. The models need to include both spatial and temporal components.
Research Gaps and Opportunities	• Enhancing knowledge, skills and expertise of all marine stakeholders, including managers and regulators, policy makers, industry and Māori, to ensure uptake of research in the development and management of marine resources. • Developing effective outreach initiatives to inform and educate the youth and general public about the oceanic realm to foster public participation in the stewardship, development and use of marine resources. • Enhanced coordination and support of marine research, especially for coastal research, which focus and leverage existing capability across all providers, encourage industry participation, and ensure coordination and cost-effective use of infrastructure and resources. • Increased baseline seafloor mapping and ecological studies are required expanding significantly the areas of quality survey data on seafloor resources and habitats, and mapping all priority areas of potential resource use (e.g. sedimentary basins) to inform both economic and environmental impact assessments. • Because our oceanic region offers a unique laboratory for research (plate boundaries, ocean trenches, underwater volcanism, major water-mass boundaries and currents, proximity to the Southern Ocean and Antarctica, deep water fisheries, sedimentary basins etc.), we are able to attract overseas researchers and resources through participation in international research initiatives. This includes vessels, equipment and data that New Zealand does not have access to, and represents millions of dollars leverage of additional investment in marine science. Funding to join international research programmes such as IODP, Argo, SOLAS, ICED, Ocean SITES and IMOS) is critical to increased use and management of our ocean resources, and also acts as a vehicle for building diplomatic ties with other nations
	Development of this National Science Challenge has been undertaken collaboratively by NIWA, GNS Science and the University of Otago. New Zealand has the science infrastructure and skills to advance the goal and themes of the Challenge. Infrastructure includes coastal vessels (universities, NIWA), a world class deep water research vessel (RV Tangaroa) and associated equipment, high performance computing and databases (GNS Science, NIWA, universities), aquaculture research facilities (Cawthron, NIWA, universities) and laboratory facilities (all providers). Opportunities exist to leverage and gain

	access to expensive specialist offshore resources such as submersibles, and deep seismic and ocean drilling based on this capability.