Ministry of Business, Innovation & Employment

National Science Challenges

Potential Challenges for Consideration by Peak Panel

Inclusive, Innovative and Secure Society

February 2013

CONFIDENTIAL – NOT GOVERNMENT POLICY

Table of Contents

1 Introduction

Forty three 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
Housing	
71	To capture new and existing social science data in such a way that it can be used for building computer models of key aspects of New Zealand society to assist with public policy development.
262	To deliver a New Zealand housing infrastructure through a building industry that can deliver well-priced dwellings that meet the needs New Zealand's diverse households and the housing market with dwellings that are real-value - resilient, efficient, affordable
321	Great Places to Live: Transforming New Zealand's Housing
329	New Zealand's residential built environment (i.e. homes and neighbourhoods) is a recognised asset that is managed to deliver value to the nation
360	How can we enable healthy, socially enabled, and environmentally sustainable communities at a time of increasing land pressures from population growth, agri-business demands and the desires for retention and enhancement of indigenous biodiversity
375	Attaining and maintaining fit-for-purpose neighbourhoods and houses in New Zealand cities and settlements that are affordable, healthy, efficiently connected and well designed
451	Connecting People. Achieve skills development, social cohesion and economic growth for New Zealand by developing, understanding and exploiting new technologies for communicating throughout New Zealand and with the rest of the world
Built Environment	
169	A climate that supports human health and wellbeing
345	A challenge for New Zealand is that construction and production processes are inefficient and unsustainable. We need to improve the efficiency of construction and industrial production systems in New Zealand.
425	Sustainable cities and societies
450	Smart, Safe, Sustainable Cities - Rebuilding Christchurch and Beyond
465	Creating positive urban futures
Society and Culture	
48	Supportive, creative and diverse communities
92	A gross happiness index to add a further dimension land review the concept of GDP in economic planning

240	To develop a risk management strategy to optimise New Zealanders' well-being if, because of external factors, New Zealand experiences very low economic growth for a sustained period
278	Supporting a thriving and productive New Zealand: Maintaining high levels of material and subjective wellbeing requires scientific approaches that underpin responsive and tailored policies that respond to a dynamic and changing economy and society
292	To enhance the role of human capital in New Zealand's economic growth
325	Fostering an innovative and cohesive New Zealand culture
341	To develop culturally responsive science teaching (CRST). Using the cultural knowledge, prior experiences, frames of reference, and learning approaches of ethnically diverse students to make learning encounters more relevant and effective for them
364	For New Zealand to have the cleanest water, safest food, least communicable disease in the world, thereby be the best place in the world to live
386	Building a flourishing e-Society
416	Scientific, Technological, Engineering and Mathematical contributions which assist New Zealand to better compete in the Global Market Place
472	Nurturing tomorrow's citizens today
Crime	
210	In New Zealand Refugees are believed not to integrate successfully. The goal will be to identify factors within the Criminal Justice System which contribute to the unemployment and underpayment of refugees which will lead to address these issues
423	New science, frameworks, approaches and tools are needed to ensure a sustained reduction in crime in the community and at the border. Our vision is of a New Zealand that is a safe place for all to live and prosper free from the social and economic costs of crime
Equitable Outcomes	
298	Better life opportunities for school leavers of Māori and Pasifika and lower socio economic background by breaking the cycle of under achievement and addressing the issues that affect their education and youth environment
478	Mātauranga: Valuing and enhancing Māori and Pacific knowledge and assets
483	Building a High Equity Society - To achieve national prosperity, we will need to achieve a progressive, free, democratic and high equity society, recognising the special place of Māori while embracing the multicultural society we have become and our future generations
Resilience to Hazards	
90	Understanding the likely impacts of anticipated changes in land cover and usage, and in climate change, on wildfire threat will be a key considerations for any approach to forest and rural fire management in the regions
172	By accelerating the understanding of natural hazard processes, their impacts and

	mitigation options, coordinated through the Natural Hazards Research Platform, New Zealand will have more social and economic resilience, and will become a world leader in national risk management
193	To make our economy, infrastructure and society as resilient as they can be to the effects of natural disasters. Resilience infers an ability to survive a crisis and thrive in a world of uncertainty
243	Adequately find the characteristics of active and inactive faults especially in or near major urban areas
253	Highly detailed, high quality mapping of New Zealand's terrain using LIDAR for infrastructure and hazard planning
269	Resilient and safe communities even in the face of natural disaster. This is to be achieved through making our energy supply and information technologies resilient to loss or damage
291	Understand the likely impacts of changes in social, environmental and economic outcomes in regard to wildfire threat in New Zealand
357	New Zealand is vulnerable to a range of geo and climatic hazards and the goal of the Challenge is to improve New Zealand's resilience to these types of hazards.
400	Big data strategies for tackling 'wicked' problems. - Climate change, sustainability and the effectiveness of emergency response systems are all part of the 'wicked' problems facing both our farms and cities in the 21st Century. Big data should now be used by the science community to solve these
433	Resilience to hazards / coping with natural disasters
445	Communities resilient to biotic and abiotic hazards
463	Increased Resilience to Natural Hazards. Goal: To increase New Zealand's economic and social resilience to natural hazards, by quantifying the risk to production, infrastructure and community activities, based on accelerating the understanding of hazard processes, impacts and mitigation options
466	Safe, Healthy and Resilient Communities
482	Infrastructure, hazards and us
485	Fire, a natural hazard: resilience and prosperity.

2 Housing

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
71	To capture new and existing social science data in such a way that it can be used for building computer models of key aspects of New Zealand society to assist with public policy development.	1. To identify and collate new and existing social science data and establish it in an "open science" collaboration so that any accredited user can start interrogating it. 2. To build computer models using the now-established data platform and infrastructure on key features of New Zealand society and its functioning. 3. To use the computer models to inform policy and other discussions of relevance to public policy and societal understanding. 4. To return to data sources and infrastructure to see what needs to be done to improve the information system so far established.
262	To deliver a New Zealand housing infrastructure through a building industry that can deliver well-priced dwellings that meet the needs New Zealand's diverse households and the housing market with dwellings that are real-value - resilient, efficient, affordable	5. The relationship between construction costs, affordability and dwelling performance and amenity expectations 6. The impact of low economies of scale 7. How consenting processes and compliance processes impact on affordable dwellings 8. Why supplying affordable dwellings appears not to be attractive to the building industry
321	Great Places to Live: Transforming New Zealand's Housing	1. Affordable Housing 2. Lifetime Housing 3. Delivering High-Performance Housing
329	New Zealand's residential built environment (i.e. homes and neighbourhoods) is a recognised asset that is managed to deliver value to the nation.	1. Developing investment models to enable sound asset management: current mix of private, business and state investment is a barrier to delivery of good quality, fit for purpose homes and neighbourhoods that deliver high value to residents and the New Zealand economy 2. Transforming homes and neighbourhoods to improve outcomes for all New Zealanders: i.e. reverse the current trend of sub-standard stock and poorly planned neighbourhoods contributing to ill-health, poverty, inefficient resource use and environmental degradation
360	How can we enable healthy, socially enabled, and	1. Understanding New Zealand demographics, housing preferences and patterns

	environmentally sustainable communities at a time of increasing land pressures from population growth, agri-business demands and the desires for retention and enhancement of indigenous biodiversity	2. Design, technology and costs 3. Community housing models and scenarios 4. Planning processes and communication
375	Attaining and maintaining fit-for-purpose neighbourhoods and houses in New Zealand cities and settlements that are affordable, healthy, efficiently connected and well designed	1. Understanding New Zealand's present and future residential urban form and development needs 2. Interdisciplinary urban research to inform decision-making 3. Managing the effective transition to high quality neighbourhoods and housing 4. Effective science communication with communities of interest
451	Connecting People. Achieve skills development, social cohesion and economic growth for New Zealand by developing, understanding and exploiting new technologies for communicating throughout New Zealand and with the rest of the world.	To develop a new communication theory that is appropriate for the modern era, and to create technology that will allow people to communicate remotely and naturally with individuals or whole crowds as if they were having a face to face conversation

Entry ID	**71**
To capture new and existing social science data in such a way that it can be used for building computer models of key aspects of New Zealand society to assist with public policy development.	
Summary	This research proposes to identify and collect new and existing social science data, and establish a database/framework for collating this data that is openly accessible (to accredited users). This data can be used to build predictive models of how specific elements of society function (e.g. infrastructure), which can be used to inform discussions/mediate change in current areas of public policy/societal understanding. A strong research component involves constantly monitoring the performance of this database/its models in order to make continual improvements.
Theme 1 **To identify and collate new and existing social science data and establish it in an "open science" collaboration so that any accredited user can start interrogating it.**	
Importance	New Zealand collects a lot of worthwhile data, but it is not readily available for

to New Zealand	external or shared use. This represents a huge opportunity cost, both for the lack of further use of the data (often collected at great cost) and for the (so far) lost potential it has for scientific and policy application.
Research components	This theme requires computer science and social science expertise, perhaps with some library skills as well, since it would involve identifying social science data and integrating it into a growing platform or infrastructure that could then be open for wider use.
Theme 2 **To build computer models using the now-established data platform and infrastructure on key features of New Zealand society and its functioning.**	
Importance to New Zealand	At present we are hard-pressed to be able to represent rigorously almost any important feature of New Zealand society, except perhaps the economy (the Treasury has various working models). This means that a lot of decisions - particularly about the future - are made with more or less robust guesstimates, rather than supported by what the most advanced modelling and forecasting techniques that social science and computational expertise can supply.
Research components	It is possible to identify the different components of a functioning society and see what models could be developed in each. This would be on analogy with, say, the human body which has different working parts, although there can be no exact analogy since so much more is known about the one compared to the other.
Theme 3 **To use the computer models to inform policy and other discussions of relevance to public policy and societal understanding.**	
Importance to New Zealand	At present we have poorly-informed decisions in public policy and a pretty rudimentary understanding of how New Zealand society works because we do not have adequate data and we do not use the data we have with sufficient sophistication and access.
Research components	The different models developed under theme 2 would be tested against policy settings and other features of what we understand about New Zealand society in order to test their validity and for them to inform future directions.
Theme 4 **To return to data sources and infrastructure to see what needs to be done to improve the information system so far established.**	
Importance to New Zealand	At present we are hard-pressed to be able to represent rigorously almost any important feature of New Zealand society, except perhaps the economy (the Treasury has various working models). This means that a lot of decisions - particularly about the future - are made with more or less robust guesstimates, rather than supported by what the most advanced modelling and forecasting techniques that social science and computational expertise can supply.
Research components	This is a feed-back loop into the information system that is "New Zealand Incorporated" to ensure that data are improved, access to those data is improved,

	and the community of users is expanded and up skilled.
Research Gaps and Opportunities	New Zealand does not currently have a centre of expertise in social and economic modelling comparable with, say, the centre of a similar name at the University of Canberra (closer to home), and elsewhere overseas. New Zealand has some unique advantages as a small society with an unusual and in many way world-leading social and cultural configuration that makes it potentially of great international interest.
Comments	This is an "open science" collaboration approach the ethos of which is to unlock data so as many as possible can use it, but with a core of modelling expertise at its core to give it direction and solidity.

Entry ID	**262**
To deliver a New Zealand housing infrastructure through a building industry that can deliver well-priced dwellings that meet the needs New Zealand's diverse households and the housing market with dwellings that are real-value - resilient, efficient, affordable	
Summary	This challenge proposes a research programme into the development of housing infrastructure in New Zealand that can deliver affordable dwellings that meet the needs of New Zealand's diverse households. Research components include the impacts of construction costs, low economies of scale, consent and compliance processes on the price of dwellings.
Theme 1 **The relationship between construction costs, affordability and dwelling performance and amenity expectations**	
Importance to New Zealand	By 2016, 68,000-108,000 new affordable dwellings will be required. All evidence suggests that the building industry will not deliver those dwellings. This is part of a persistent trend in the industry's focus on houses in the upper quartile; poor productivity and poor quality. 2001-2006, the building industry delivered 125,000 dwellings but under-supplied affordable dwellings by 115,000; construction prices are up to 26% higher than Melbourne or the Gold Coast; significant numbers of households are exposed to risks to their housing through poor building and construction. Low production dwelling in the lower prices quartiles have stranded middle and low income households in persistent housing stress. Those unable to access public housing, in employment but unable to afford home ownership doubled between 2001 and 2006 and is likely to constitute up to 280,000 households by 2016. 35% of tenants have unaffordable rents. In 2006, 80,000 children were in temporary dwellings because of an under-supply of affordable housing and 25% of children in eight districts in New Zealand lived in over-crowded dwellings for the same reason.

	Housing stress is associated poor economic and social outcomes and externalised costs in health and welfare. It drives a significant fiscal burden for government with the accommodation supplement forecast to absorb between $1.7 billion and $2.3 billion of government expenditure by 2015. Under-supply of affordable housing is a barrier to economic growth, labour supply, and global competitiveness. For instance, under-supply in the Bay of Plenty will reduce forecast economic growth over two decades by about $500 million.
Research components	This needs to test longstanding but questionable arguments that regulatory and end-user expectations drive prices upwards. Building and social scientists will deliver transformational research with enabling techniques such as: 1. Consensus conferences and charettes with research-ready industry stakeholders and early adopter consumers. 2. Case studies and demonstrations where the industry and housing providers attempt to meet both affordability and other performance imperatives 3. Collaborative workshops to develop guidelines; build solutions; procurement templates; and affordable choices calculators.
Theme 2 **The impact of low economies of scale**	
Importance to New Zealand	These have persistently been cited as a reason for higher materials costs in New Zealand.
Theme 3 **How consenting processes and compliance processes impact on affordable dwellings**	
Research components	If these processes drive costs rather than the performance requirement itself, solutions can be found in the re-engineering of compliance processes rather than reducing performance with associated risks of externalized costs and higher operating costs associated with less healthy, durable and resource efficient dwellings.
Theme 4 **Why supplying affordable dwellings appears not to be attractive to the building industry**	
Research components	Associated with this issue are: the extent to which affordable housing providers and householders are able to control price through design, procurement methods or project management and, whether anxieties about price control mean householders and affordable housing providers choose not to build or rehabilitate homes.
Research Gaps and Opportunities	A variety of reasons have been given as the drivers for New Zealand's higher building costs and the building industries under delivery of affordable dwellings. Building materials and transport costs, limited opportunities for economies of scale, cover-bidding, deskilling, industry fragmentation, dominance by a few vertically integrated companies, innovation inertia, low productivity, rising statutory and market performance requirements, are all cited as possible drivers. The reality is the evidential base is simply inadequate to come to any conclusions

	and the debate is marked by often contradictory, speculative polemic. This must change. To date, two domains related to housing affordability – land use/ settlement planning and demand in housing markets – have attracted a significant research investment. Research into the role and transformation of the building industry in the delivery of affordably priced dwellings has been neglected. There is a persistent under-investment in this area. This is despite New Zealand having research capacity to address both industry performance and opportunities to deliver affordable priced housing to housing providers – social, private and community landlords and alternative tenure providers such as retirement villages, rent for buy trusts, and shared ownership trusts – and households on the margins of home ownership. This requires that research funding builds on research collaborations in the building/housing nexus that are both cross-organisational and cross-disciplinary. To break out of the current cul-de-sac requires a transformational research programme connected to cross-industry, household, housing and community sectors, that generate effective tools for change as well as a robust informational base.
Comments	New Zealand has a significant housing crisis already which partly reflects the operation of the housing sector and problems around transforming latent demand into actualise demand. This constantly is the focus of debate and research has been pursued in this. The building industry as a contributor to the public good and economic and social well-being has simply been neglected, despite a series of reports critical of it over the last decades. Its time it was taken seriously before it really is too late for both the industry and families and the opportunity for fit-for-purpose housing is lost.

Entry ID	**321**
Great Places to Live: Transforming New Zealand's Housing	
Summary	The goal is to create housing stock that meets New Zealand's need better. Themes include developing effective vehicles for delivering affordable homes and rental housing, developing a greater multigenerational housing stock in response to an ageing population, developing new systems and technologies to deliver high-performance housing that is resilient to changing climate and social and economic needs
Theme 1 **Affordable Housing**	
Importance to New Zealand	The last decade has seen changes in housing affordability, in particular for households looking to buy a home. Productivity Commission figures show the national house price to disposable income ratio rose from around 2 to 1 in 1980 to 5 to 1in 2012. Figures from the New Zealand Government Treasury also show the percentage of gross income required for an average mortgage payment grew from

	around 35% in the mid-1990s to a high of 65% in 2008. It is now around 45%. Housing affordability is a significant issue in many parts of the country, in particular in housing markets such as Auckland where pressures exist around both rents and home ownership. It is forecast that New Zealand's population will reach 4.8 million people by 2021. Growth is not expected to be distributed evenly amongst the regions – the populations of cities are growing, particularly in the Auckland triangle (Tauranga, Hamilton, Whangarei). Linked to changes in affordability has been the decline in levels of home ownership. In recent decades, home ownership was highest in the 1991 Census, at 73.8 percent. By 2006 it had declined to 66.9%. For Māori, the figures are much lower, with home ownership having fallen from 31.7% in 2001 to 30.1% in 2006. With more and more New Zealanders living in rental housing either as a positive choice or because they cannot access home ownership, the availability and quality of rental housing provision is growing in importance.
Research components	• Transforming the rental market: Alternative tenure models to support a strong, cohesive society. • Optimising the home ownership market: models for a functional market. • Developing effective vehicles for delivering truly affordable homes and rental housing. • Developing baseline techniques and mechanisms for measuring progress. • Genuine identification of New Zealander's current and future housing needs: who is having difficulty accessing suitable housing? What are their actual housing requirements (social, cultural, economic)?
Theme 2 **Lifetime Housing**	
Importance to New Zealand	The ethnic make-up of New Zealand's population is also changing, with the Māori, Asian, and Pacific populations making up a growing proportion of the overall New Zealand population. The cultural diversity of New Zealand's population will continue to increase and this may also influence future housing needs – for example if there is a demand for a greater multi-generational housing stock. All ethnic groups will age in the coming decades. By 2051, there will be over 1.14 million people aged 65 years and over in New Zealand. This represents an increase of 715,000 or 166 percent over the base (1996) population. They are expected to make up 25.5 percent of all New Zealanders. At present there are about half as many elderly New Zealanders as children. By 2051, there are projected to be at least 60 percent more elderly than children. Given the prospects of sub-replacement fertility, increasing life expectancy and the ageing of baby boomers, it is projected that half of all New Zealanders will be older than 46 years by 2051, compared with the current median age of 34 years. The housing needs of an aging population will not be met by current housing stock. Demand will increase for more liveable, lower maintenance homes. As people retire employment will no longer tether people to particular places and the drivers for choice of location will change. Many may choose to locate away from major centres of employment. For some retirement at age 65 may not be

	desirable or feasible.
Research components	• Moving to "future-fit" from retrofit: Developing and defining inclusive design principles. • Recognising the value of Lifetime Housing: Tools, methods, and standards for genuine whole-of-life value analysis and systems (including maintenance, operations and adaptation costs).
Theme 3 **Delivering High-Performance Housing**	
Importance to New Zealand	Buildings are fundamental to our way of life, not only are they where we live, work and play, they are the foundations of our economy and represent the majority of fixed assets in New Zealand. Improving the quality, function and performance of our buildings is a vital foundation for supporting New Zealand's economic growth. Providing good-quality buildings, including housing, schools, workplaces etc, in the future is important for all New Zealanders. The Canterbury earthquakes have reinforced the critical importance of the design and construction of buildings that are resilient to the particular challenges of New Zealand's natural environment. The cost of natural disasters to the insurance industry is high. Over the last five years, excluding claims arising from the Canterbury earthquake events, the insurance industry has paid out more than $360 million in claims relating to damage caused by natural hazards. New technology development is happening at an unprecedented pace and we are starting to see how the power of technology can be applied to the building and construction industry and transform the way we work. As technology continues to develop there are likely to be more opportunities to utilise technologies and construction methods such as off-site manufacture and prefabrication of components, panels, modules, and complete buildings. These will help achieve efficiencies and improve productivity through for example consistency of quality and reduction of weather delays. The quality of housing strongly correlated with health and education outcomes, with poor quality housing contributing to high health needs and poor education outcomes.
Research components	• Systems and new technologies incorporating innovative, durable materials and building processes. Achieving housing design that is resilient to changing social and economic needs. • Achieving housing that is resilient to New Zealand's current and future climate and climate variability.
Research Gaps and Opportunities	The Building and Construction industry is New Zealand's fifth largest sector. It contributes about 4.3% to GDP and employs one in every 12 New Zealanders in the workforce. Output from the sector dominates New Zealand's investment, contributing some 45% of all Gross Fixed Capital Formation. The sector also plays by far the largest role in building New Zealand's infrastructure stock, which is the foundation of productivity and economic growth. One dollar invested in building and construction, delivers three dollars in economic activity across the economy. In 2012, at an estimated value of over $650 billion, the housing stock represents the majority of the country's individual wealth and the most identifiable single

	source of retirement security. Housing is critical; as it provides shelter and supports the productive healthy lives of its inhabitants We face the distinct challenge and opportunity of rebuilding one of our New Zealand's largest cities, Christchurch. New ideas and solutions will be needed as a generation of work re-shapes much of the city's buildings. Similarly Auckland will undergo significant change over the next few decades as its population grows by 40% from its current 1.34 million to 2.5million by 2040. We are expecting to see further concentration of employment and high value production activities in the Auckland region. If we are to meet these twin challenges, and influence and improve building and construction across the whole of New Zealand, then changes in what and how we build will be required. The building and construction industry is increasingly complex and we need to understand the impacts that decisions in one area have on the rest of the system and New Zealand as a whole.

Entry ID	**329**
New Zealand's residential built environment (i.e. homes and neighbourhoods) is a recognised asset that is managed to deliver value to the nation	
Summary	This challenge proposes to develop means to transform our residential built environment into a recognised asset that provides benefit and improved outcomes for the whole nation. This will require the current trend of sub-standard housing stock and poorly planned neighbourhoods to be reversed, via a combination of research which involves improving housing construction (i.e. with innovative building materials), improving urban planning, and developing a national evaluation framework which guides management of such valuable properties as an asset (this will require investigation of various economic aspects, business models, generating stakeholder interest etc.).
Theme 1 **Developing investment models to enable sound asset management: current mix of private, business and state investment is a barrier to delivery of good quality, fit for purpose homes and neighbourhoods that deliver high value to residents and the New Zealand economy**	
Importance to New Zealand	Current residential investment is fragmented, unreliable over long term and the cost benefit picture is complex. New partnerships are needed to release capital, share risk across stakeholders and recognise the value of investing in homes is more than 'private capital gain'. Stakeholders include: utilities (reduce demand for reticulated energy and water, technical innovation), banks ("own" majority of the asset via mortgages), insurers (Canterbury earthquakes engaged in housing issues), central/local government (carry risk when market fails, e.g. $11.3 billion for leaky buildings, fund interventions, e.g. WUNZ, meet health/environment costs), construction industry (facing poor productivity, low skills/training), third sector (developing, focus on affordable housing/poorest households), communities, and residents.

	The residential sector is a large source of employment: house building/renovation is worth >$12.0 billion annually and directly employs 8% of the workforce. Beacon's research identified that: for every 1,000 houses retrofitted, 151 FTE jobs are needed for delivery of on-site services, and 392 FTE jobs are needed to provide the products and services; and, upgrading the housing stock to a high standard would generate a direct private economic gain to households equivalent to one percent of GDP by 2017 (non-monetary benefits of healthier and more comfortable homes, and environmental benefits, additional). Auckland and Canterbury are in residential crisis with significant unmet demand for homes. New business models to deliver could unlock the shortfall (Auckland needs 150-200,000 homes in 20 years; Canterbury needs 5,000 homes per year for next four years). Preventing future market failures in New Zealand, like leaky building, must be a major priority for cost avoidance.
Research components	• Identify optimal policies for central and local government to: stimulate asset investment to achieve wider outcomes; demonstrate leadership opportunities to establish homes and neighbourhoods as a national asset; develop strategies to better manage risk of market failure; and, improve management of own stock to achieve wider objectives (e.g. health, poverty alleviation, minimising environmental impact). • Analyse the roles that need to be played to deliver high quality, fit for purpose homes (new and existing) and neighbourhoods (develop new or regenerate existing) to achieve good outcomes. Assess the nature of each organisations stake, appetite for risk and capacity to deliver and develop new innovative ways to partner (and fund) to improve residential outcomes. • Demonstrate and evaluate a range of partnerships and business models against criteria set for investing to improve New Zealand's residential asset. Scale up successful models, actively learn from failures.
Theme 2 **Transforming homes and neighbourhoods to improve outcomes for all New Zealander's: i.e. reverse the current trend of sub-standard stock and poorly planned neighbourhoods contributing to ill-health, poverty, inefficient resource use & environmental degradation**	
Importance to New Zealand	The poor performance of New Zealand's housing stock is well documented and links to poor health outcomes are published in international peer-reviewed literature. In brief: New Zealand's "OECD record" of highest rate of winter morbidity, high respiratory illness rates and increasing infectious disease incidence. The cost of one night's stay for an asthmatic patient is in excess of $2,000; recognised as exceeding the costs to insulate a home. While causes of poor health are complex, poor housing is key contributor and offers a tangible intervention point and avoidance of indirect costs of the degraded asset. Beacon's national value case estimated that by upgrading 90% of New Zealand's housing stock to a high standard New Zealand could save 22 PJ/year (power more than 500,000 homes for a year) and 130 million m^3/year of potable water. Reticulated water demands significant energy to transport, treat and manage: a 'hidden burden' met by councils/rate-payers. Neighbourhood sustainability and resilience can impact at both an individual home and at the city level. Neighbourhoods also represent significant economic, cultural and emotional

	investment and attachment, often accrued over a great length of time. But neighbourhoods not static: in fact, in order to be sustainable and resilient, neighbourhoods need to be diverse and dynamic, as shown in the recovery phases following the Christchurch earthquakes of 2010-11. Beacon's research indicates that high density/ mixed use neighbourhoods show higher dollar sustainability values than low density, non-mixed use.
Research components	• Develop national evaluation framework to guide management of New Zealand homes and neighbourhoods as an 'asset' and provide stable evidence base for current and future decision making about residential interventions (e.g. align and extend existing datasets: BRANZ house condition survey, health statistics, census etc). • Identify the gaps in current stakeholder capacity, e.g. skills training already known to be a barrier to high quality housing outcomes and make strategic plan to fill them within the wider context of managing New Zealand's residential asset. • Develop and demonstrate innovative prefabricated methods of delivering quality new homes to the market that meet resident's needs (affordability, typology, size, solar orientation etc.). Identify new models of delivering rental properties that will unlock the poor quality, expensive and low supply that our current models of residential development offer: one third of New Zealand's housing stock is rented and is in very poor condition, with majority provided by private sector (most of whom own less than 7 properties, i.e. 'mum and dad capital gain investors'). • Identify appropriate scale of intervention for different stakeholders and project purpose, i.e. when is it best to engage at level of individual home, neighbourhoods, a city, or nation-wide? • Develop innovative systems for distributed energy and water systems for New Zealand neighbourhoods, to improve performance, resource efficiency and resilience outcomes. • Demonstrate innovative neighbourhood interventions (new developments and rejuvenating existing) in collaboration with community and partnership of funders and experts. Beacon has New Zealand-tested neighbourhood tools unique in capturing community voice offering a robust framework to demonstrate.
Research Gaps and Opportunities	As noted, the state of New Zealand's substandard housing stock is well documented, as are enough of the related poor outcomes to highlight the issues. Therefore, the gap is applied research: how best to transform the country's residential built environment? A common goal (by valuing the residential sector like an asset) and agreed means of evaluating outcomes would integrate much of the existing and planned work. Providing a transparent means of assessing what interventions, policies, projects, partnerships worked and what didn't would develop a valuable evidence base for New Zealand. This is essential to underpin good integrated decision making about New Zealand homes and neighbourhoods. There is an opportunity to be a world leader through transformation of our homes and neighbourhoods and potentially export innovations (e.g. technical, evaluative tools, policy approaches, business models).
Comments	While some parts of this proposed work is underway, or in a pipeline in a New Zealand organisation, the fragmented, non-integrated way the

	research/interventions are conducted and managed contributes to the 'problem'. The proposed re-framing of the residential sector is an attempt to provide a nationally strategic approach against which different initiatives can be co-ordinated, trialled and learning captured. The required transformation -has regional elements, e.g. Canterbury rebuild; -needs multidisciplinary input (e.g. community liaison, social/cultural skills, economics, policy/evaluative tool development, health, disaster preparedness, business, innovation and building science); and, -demands complex institutional responses, i.e. action on multiple fronts with a variety of partnerships and funding models.

Entry ID	**360**
How can we enable healthy, socially enabled, and environmentally sustainable communities at a time of increasing land pressures from population growth, agri-business demands and the desires for retention and enhancement of indigenous biodiversity	
Summary	The goal is to plan high quality future living and community spaces in New Zealand. Themes include understanding New Zealand demographics, housing preferences and patterns to make settlements more efficient while retaining the essential elements of wellbeing that make them socially viable, anticipating housing technology/design developments and identifying future cost scenarios, developing future community housing models and scenarios, developing housing research, design and implementation systems that include the engineering and planning professions fully
Theme 1 **Understanding New Zealand demographics, housing preferences and patterns**	
Importance to New Zealand	New Zealand is a highly (>80 %) urbanised society. As a post-industrial settlement we present extremely low urban densities, which are therefore energy intensive (especially through) transport links, and continue to spread onto fertile agricultural land. For New Zealand to play its role in feeding the growing world population and in so doing reap economic benefits how can we make our settlements more efficient while retaining the essential elements of wellbeing that make them socially viable and more environmentally sustainable places to live, work and visit. Primary production is currently about 60 percent of our income and tourism 16 percent. While difficult to quantify, future benefits of maintaining and enhancing the mix from these sectors is our core global trading position.
Research components	1. Identify changes in New Zealand demographic (age /ethic/ urbanisation) drivers for 10, 25 and 50 year drivers 2. Identify key dimensions of, and barriers to, national (and ethnic) housing patterns and preferences {kaitiakitanga of Urban settlements, CO9X0907}

	3. Determine a key set of national and ethnic 'Housing preferences' and sub-urban landscape design preferences
Theme 2 **Design, technology and costs**	
Importance to New Zealand	Design elements for both living and community spaces need to be set against real and anticipated technology development to determine cost functions (efficiencies) to house the anticipated 6 million New Zealanders by 2030, and potentially 8 million by 2050.
1. Research components	4. Identify technology drivers and potential changes in transport for 10, 25 and 50 year scenarios. 5. Identify technology drivers and potential changes in design for healthy living: 6. Housing form function and cost 7. Community /neighbourhood: socially connected, community focussed, active life style enabled (Urban Form Victoria and Otago universities). 8. Identify cost drivers in for future scenarios 9. Identify relationships between character of urban green infrastructure and liveability of New Zealand cities 10. Determine improved configuration of urban green under increasing densities and develop guidelines for design and management 11. Land. Housing. Transport. {Health (NIWA); Future Streets for Auckland (TREX1201)}
Theme 3 **Community housing models and scenarios**	
Importance to New Zealand	Planned options need to be both socially accepted and financially realistic. Evidence from current Christchurch rebuild (including a current competition for higher density housing) we be most useful in providing baseline costs for various community /housing outcomes.
Research components	1. Define qualitative and quantitative model for future housing /community scenarios. 2. Explore outcomes for risk and resilience drivers and their costs (links to natural hazards platform) {refer Resilient Urban Futures UOOX1203}. 3. Run scenarios for 10, 25 and 50 years
Theme 4 **Planning processes and communications**	
Importance to New Zealand	Any research must progress from 'scientific outputs' to social and environmental outcomes. This theme ensures that the planning and engineering professions will be included fully in the research design, implementation and outputs to address the challenge as set out.
Research components	1. Undertake reviewing of urban planning law(s), policy and processes (e.g. consents, densities, open space, design...). 2. Innovation in science communications to inform planning and design practice
Research Gaps and	As indicated throughout the description of research themes there are a number of

Opportunities	research projects underway at the present. Notwithstanding significant gaps exist around: * social and cultural understandings of housing preferences * Future population scenarios * Urban green infrastructures * planning and policy enablers; and the cooperative structures that would address the challenge as a whole
Comments	Close to eighty percent of New Zealand citizens now live in urban settlements. The significant challenge lies in continuing to shape healthy, socially enabled, and environmentally sustainable communities at a time of increasing land pressures from population growth, agri-business demands and the desires for retention and enhancement of indigenous biodiversity. While there are a number of science projects currently being undertaken in New Zealand the result is one of competitive processes and lack of a unified vision of the larger picture. What is proposed is a national collaboration to integrate current research and undertake the sequence of projects identified above to provide a comprehensive roadmap for housing form and function into the future.

Entry ID	**375**
Attaining and maintaining fit-for-purpose neighbourhoods and houses in New Zealand cities and settlements that are affordable, healthy, efficiently connected and well designed	
Summary	This challenge proposes to attain/maintain well-suited housing that is affordable, healthy, efficiently connected and well designed. Research will need to address New Zealand's present and future housing development needs, through the integration of multiple lines of research to inform decision making (societal needs/demands for housing, urban/rural infrastructure, sustainable building materials etc.). Research will also focus on how to effectively manage the transition to such 'high-quality neighbourhoods', which will involve effective means of interaction/science communication with affected communities/communities of interest.
Theme 1 **Understanding New Zealand's present and future residential urban form and development needs**	
Importance to New Zealand	It is important to provide both baseline data and future scenarios for residential urban form and development. House and home are central to the quality of all New Zealanders' lives along all dimensions. Without decent affordable shelter all else becomes highly problematic.
Research components	• Identify current and future social, physical and neighbourhood forms, residents' capacity to create and support high quality ways of living, relationships to wider urban networks, and connected-ness to employment, education, transportation, amenity, heritage, recreation, open spaces, bio-diverse natural areas and quality social interactions.

	• Understanding housing needs including affordability, design, durable building materials, form, density, size, tenure, diversity, changing life cycle requirements, and future-proofing for performance. Investigating issues regarding the supply of housing and the development cycle. • Understanding the functioning of neighbourhoods and houses, including resilience, capacity for change, energy efficiency, liveability, sense of place and social acceptability. Interpreting the willingness of market participants to purchase new housing forms. Investigating the potential of neighbourhoods and houses to be the sites of significant climate change mitigation.
Theme 2 **Interdisciplinary urban research to inform decision-making**	
Importance to New Zealand	Research into neighbourhoods and housing is very complex and multi-faceted and this demands an interdisciplinary approach in order to provide data and analysis for effective decision-making.
Research components	• Identifying societal needs and demands for neighbourhoods and houses. Investigating the appetite for new ways of living, providing and managing social housing, understanding developer and investor decision-making and property finance and markets. Understanding planning and urban design at the neighbourhood level, provision of services and attractive high-amenity open space. Ensuring that existing preferred heritage neighbourhood landscapes and their elements are preserved. • Develop governance, decision-making, planning and design frameworks and tools for long, medium and short-term development of neighbourhoods and housing taking account of current settlement patterns and contexts. Also incorporate research into developers' decision-making on the timing, quality and cost of development.
Theme 3 **Managing the effective transition to high quality neighbourhoods and housing**	
Importance to New Zealand	An effective transition to high quality neighbourhoods and housing will require the development of a new range of tools, techniques, relationships and forms of organisation and governance.
Research components	• Develop technologies and construction systems to improve the performance, affordability, integration and natural environmental integrity of neighbourhoods and housing. Examining options for increasing scale within the residential construction industry to take advantage of associated economies. • Develop tools, monitoring methods and design standards to meet fit-for-purpose neighbourhoods and housing that are affordable, healthy, efficiently connected and well designed and durable.
Theme 4 **Effective science communication with communities of interest**	
Importance to New Zealand	Excellent research demands first class communication of results and effective interaction with all those who can use or who may be affected by them.
Research components	• Recognising that education is a key way of connecting communities, develop an interactive strategy between researchers and end-users to communicate research findings about improved neighbourhoods and housing to the widest possible range of interests in New Zealand and internationally.

	• Developing consistent and meaningful and communication between designers, planners, investors, developers and residents. Engaging in international debates in the area of urban research and urban residential intensification. Promoting social and cultural change and different relationships with the environment consistent with requirements for new and more diverse neighbourhood and housing forms.
Research Gaps and Opportunities	Housing and a sense of home and place are centrally important in the creation of a well-functioning, just and economically successful society. Many neighbourhoods and houses in New Zealand are unaffordable for significant segments of the population and at the national level home ownership rates are falling. The rental market is not sophisticated. A significant proportion of the housing stock is unhealthy, poorly designed, non-durable, and inefficiently connected to wider networks of social, cultural and economic activity. New technologies are emerging such as distributed electricity generation (photo-voltaics), electric cars and house pre-fabrication which have the potential to affect neighbourhood and house forms. Pressures are mounting for more intensified residential environments. The creation of new knowledge for innovative, effective and positive urban residential futures requires a much stronger interdisciplinary focus combining the social sciences (including economics and finance), planning, design, construction, engineering and ecology. The neighbourhood and housing challenge is amenable to amelioration through the creation of new knowledge derived from effective mission-led research. There exists the capacity to conduct the interdisciplinary research required but to date funding has not been made available on a broad enough scale over a sustained period of time. We have good economic data and analysis from the recent work of the Productivity Commission but this is only part of the story. Work particularly with a social focus integrated with the work of other disciplines examining the key agents in urban development such as financiers, investors, developers, builders, construction product manufacturers and planners, and their decision-making processes, is badly needed. So too is work associated with New Zealanders' uses and preferences for their neighbourhoods and housing.

Entry ID	**451**
Connecting People. Achieve skills development, social cohesion and economic growth for New Zealand by developing, understanding and exploiting new technologies for communicating throughout New Zealand and with the rest of the world	
Summary	The goal of this proposal is to develop a new communication theory that is appropriate for the modern era, and to create technology that will allow people to communicate remotely and naturally with individuals or whole crowds as if they were having a face to face conversation. This challenge requires the collaboration between several disciplines. Electrical and computing engineering

	(to contribute to the development of efficient and sustainable communication infrastructure); computer science (to tackle the development of communication tools that build upon the communication infrastructure); psychology and other socio-behavioural sciences (to help us understand how we can design these tools to be optimal for diverse users etc.
Theme 1 **To develop a new communication theory that is appropriate for the modern era, and to create technology that will allow people to communicate remotely and naturally with individuals or whole crowds as if they were having a face to face conversation**	
Importance to New Zealand	Communication is critical for every community. Fostering connections between people is a core function of society. New Zealand in particular depends on efficient communication with the rest of the world due to its geographic isolation. Staying in touch with friends and family members abroad, creating and maintaining business relationships around the globe and exchanging vital data is an absolute necessity for New Zealand's economic growth and wellbeing. But we are also faced with domestic challenges: bridging the generation gap, connecting rural areas with remote experts, overcoming the digital divide, and making the best teachers available to our children are crucial for developing a vivid and healthy society. The education of the general public about health issues, life-long learning and on-the-job training are essential new challenges that technology can help to overcome. There are other social issues to address; people can increasingly connect globally, while at the same time becoming less connected locally (we may have hundreds of Facebook friends in other countries but don't talk to our neighbours). While New Zealand is building the necessary communication infrastructure, such as ultra-high bandwidth internet access, it will need new communication tools and platforms to fully exploit that investment. It will be necessary to full understand communication processes, design new communication experiences, and develop tools for analysing the goodness of communication. Distance education, telecommuting for work, collaborative virtual environments, and community decision-making systems are new challenges that will empower our communities and relationships to grow and prosper. This will also enable New Zealand to stay competitive in a global environment in which geological distance is no longer the true obstacle. It is the interpersonal distance we need to bridge.
Research components	This challenge requires the collaboration between several disciplines. Electrical and computing engineering need to contribute to the development of efficient and sustainable communication infrastructure. Computer Science will have to tackle the development of communication tools that build upon the communication infrastructure. These tools need to provide the best possible communication, decision-making and learning experience for a wide variety of users. Psychology and other socio-behavioural sciences will help us understand how we can design these tools to be optimal for diverse users (for example, the elderly and digitally disenfranchised) and will develop efficient procedures for the use of these new technologies. What impacts will these new technologies have on individuals and

	how can we improve these technologies further? In addition, collaboration between technologists and psychologists will help society resolve outstanding issues that may impair uptake of these new technologies, such as concerns regarding privacy and access.

3 Built Environment

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
169	A climate that supports human health and wellbeing	1. Development of technology that simultaneously reduces greenhouse gas emissions and promotes health 2. Understanding the factors that promote societal adoption of healthy low carbon lifestyles and practice 3. Action oriented measurement of New Zealand's greenhouse gas emissions profile 4. This challenge will focus on developing technology that simultaneously reduces greenhouse gas emissions, whilst promoting public health e.g. energy efficient buildings that are warmer and dryer (and therefore healthier). Public engagement is vital to ensure that new technologies and practices related to mitigating climate change are widely-adopted
345	A challenge for New Zealand is that construction and production processes are inefficient and unsustainable. We need to improve the efficiency of construction and industrial production systems in New Zealand	1. The goal is to develop products and processes that result in more efficient buildings. Efficiency gains will be during construction and throughout the building's lifecycle 2. The goal is to develop industrial and manufacturing processes that require less inputs including feed materials, energy and water
425	Sustainable cities and societies	1. Designing homes, neighbourhoods and communities for the future 2. Resilient energy and infrastructure 3. Developing healthy, sustainable and affordable transport systems 4. Maximising social connectedness
450	Smart, Safe, Sustainable Cities - Rebuilding Christchurch and Beyond	1. Improving the Economic Development Potential of New Zealand Cities 2. Strengthen Community Resilience, Safety and Wellbeing 3. Built Environment / Accessible Cities 4. Regional Growth and Development
465	Creating positive urban futures:	1. Building cities as resilient, replenishing systems. 2. Growing our natural capital to underpin economic growth, social wellbeing and environmental health

Entry ID	169
A climate that supports human health and wellbeing	
Summary	This challenge will focus on developing technology that simultaneously reduces greenhouse gas emissions, whilst promoting public health e.g. energy efficient buildings that are warmer and dryer (and therefore healthier). Public engagement is vital to ensure that new technologies and practices related to mitigating climate change are widely-adopted.
Theme 1 **Development of technology that simultaneously reduces greenhouse gas emissions and promotes health**	
Importance to New Zealand	Leading scientific bodies agree that climate change is occurring and it is very likely driven by human greenhouse gas (GHG) emissions. Climate change is widely recognised by world health authorities and leading medical journals to be the biggest global health threat of the 21st century, well accepted by New Zealand medical professional bodies. Technology to reduce greenhouse gas emissions can also promote health. For example, energy efficient buildings are warmer, dryer and healthier. Transport technology that promotes cycling, walking and public transport also addresses obesity, diabetes, cardiovascular disease and the health problems associated with air pollution.
Research components	Energy efficiency Renewable energy generation Active and public transport infrastructure Waste minimisation and management Sustainable agriculture
Theme 2 **Understanding the factors that promote societal adoption of healthy low carbon lifestyles and practice**	
Importance to New Zealand	Much is already known about sustainable practice and ways to achieve healthy low carbon lifestyles. Less is known about how to effectively transition communities now and in the near future - what the enablers and barriers are.
Research components	Barriers and enablers for low carbon lifestyle change Effective communication of the health and other benefits of low carbon lifestyles and practice Measurement of the benefits of low carbon lifestyles and practice
Theme 3 **Action oriented measurement of New Zealand's greenhouse gas emissions profile**	
Importance to New Zealand	Accurate, timely and specific measurement of New Zealand's greenhouse gas emissions profile is the foundation for action and monitoring.
Research components	Real time measurement and communication of greenhouse gas emissions

Theme 4 This challenge will focus on developing technology that simultaneously reduces greenhouse gas emissions, whilst promoting public health e.g. energy efficient buildings that are warmer and dryer (and therefore healthier). Public engagement is vital to ensure that new technologies and practices related to mitigating climate change are widely-adopted	
Importance to New Zealand	Development of technology that simultaneously reduces greenhouse gas emissions and promotes health
Research components	Leading scientific bodies agree that climate change is occurring and it is very likely driven by human greenhouse gas (GHG) emissions. Climate change is widely recognised by world health authorities and leading medical journals to be the biggest global health threat of the 21st century, well accepted by New Zealand medical professional bodies. Technology to reduce greenhouse gas emissions can also promote health. For example, energy efficient buildings are warmer, dryer and healthier. Transport technology that promotes cycling, walking and public transport also addresses obesity, diabetes, cardiovascular disease and the health problems associated with air pollution.
Research Gaps and Opportunities	Energy efficiency Renewable energy generation Active and public transport infrastructure Waste minimisation and management Sustainable agriculture
Comments	Understanding the factors that promote societal adoption of healthy low carbon lifestyles and practice

Entry ID	**345**
A challenge for New Zealand is that construction and production processes are inefficient and unsustainable. We need to improve the efficiency of construction and industrial production systems in New Zealand	
Summary	The goal is to develop products and processes that result in more efficient buildings. Efficiency gains will be during construction and throughout the building's lifecycle. Themes include the development of products and processes that result in more efficient buildings (in terms of reusable and sustainable building materials and optimal design as well as development of spatial models to understand the optimal urban form use of land), the development of sustainable industrial and manufacturing processes to reduce input requirements
Theme 1 **The goal is to develop products and processes that result in more efficient buildings. Efficiency gains will be during construction and throughout the building's lifecycle**	
Importance to New Zealand	There are three areas where benefits will be realised: during construction, during the life of the building and at the end of the life of the building. The overall result will be buildings constructed from reused materials that are efficient during their lives and easier to deconstruct at the end of their lives. Buildings will be built with

	a whole of life approach applied. During construction thought will be given to the materials used and the potential for using reused materials. Doing so will reduce demand for virgin materials, reduce energy demand (used to produce virgin construction materials) and potentially reduce construction costs. It has been suggested that reusing construction materials could reduce the impact of construction by at least 10%. Reuse is important as construction and demolition represents up to half of all waste generated in New Zealand and a large amount of this could be reduced, re-used or recovered. During the life of a more efficient building energy and water consumption will be reduced, resulting in better use of New Zealand's resources and reduced costs for building users. Research suggests using low energy, low water appliances could reduce energy and water use by at least 20% and inclusion of passive solar design could reduce heating energy usage by 80%. At the end of their lives buildings will be easier to deconstruct. Where buildings are deconstructed this will enable reuse of their construction material, again resulting in less material to 'clean-fill' and better use of land and other resources.
Research components	Research components include: • Development of building materials that are more efficient and effective and sufficiently robust to enable reuse at the end of a building's life • Studies of water and energy use and the interaction between this and building materials, processes, building design and construction • Development of spatial models to better understand urban form and how building design and construction affects land use. • Identification of processes that can increase the efficiency of a building, including heating and ventilation processes, energy generation processes, and other processes. • Development of processes and products that can be used to improve the efficiency of existing buildings.
Theme 2 **The goal is to develop industrial and manufacturing processes that require less inputs including feed materials, energy and water**	
Importance to New Zealand	Increased efficiency of industrial and manufacturing processes will result in reduced material, energy and water use. This will enable better use of New Zealand's limited resources and reduce the costs to the New Zealand economy.
Research components	Research components include: • Understanding the efficiency of industrial processes and looking for alternative processes or more efficient methods • Investigating alternative feed materials to decrease the volume of feed materials needed and to identify alternatives that have other advantages such as reduced toxicity or reduced environmental or other risk • Investigating processes that enable the reuse of materials (such as waste materials) as feedstocks for other processes • Investigating methods of reducing energy use during production processes

Entry ID	425
Sustainable cities and societies	
Summary	The goal is to make both urban and rural New Zealand more liveable. Themes include designing homes, neighbourhoods and communities that are efficient in resource use and resilient to natural hazards; and social and demographic change, integrating efficient energy and infrastructure that is resilient to technological change and natural hazards into urban areas; developing affordable, healthy, sustainable, environmentally sound transport systems as an alternative to the unnecessary use of private cars; improving iwi contribution to urban development, finance and governance; and developing new models to improve effectiveness of provision of services to rural communities
Theme 1 **Designing homes, neighbourhoods and communities for the future**	
Importance to New Zealand	How can New Zealand simultaneously build resilience into our cities, lower urban dwellers' carbon footprints, and ensure security of key network services, such as electricity and water supply? How can we do this with equality of access across the whole socio-economic spectrum, with appropriate recognition for our peoples' diverse cultural needs?
Research components	• Understanding the sometimes competing drivers of urban change — such as in-fill / compact versus greenfield development — and both their intended (and unintended) economic, social and environmental outcomes is critical to making informed decisions on planning tomorrow's cities. • Cities need to not only be efficient in terms of their all-of-life resource use, but must be resilient to change - physical (e.g., earthquakes) and social (e.g., rapid in- and out-migration) - and provide a safe, healthy and liveable environment. • Developing understanding and models of these interconnecting aspects is key to developing sustainable cities that promote and maintain social cohesion.
Theme 2 **Resilient energy and infrastructure**	
Research components	• Developing integrated urban models that link infrastructure needs to different forms of urban development (taking into account land use, housing and transport) is critical to successful and cost effective urban planning. • Models need to consider efficiencies of local and inter-urban infrastructure, including ultra-fast broadband, and transport links between key hubs such as ports. • Such planning also needs to ensure the infrastructure is as future-proofed as possible to both technology changes and external physical challenges (e.g., resilience to earthquakes). • An increasingly important dimension of this will be considering the inclusion of greater renewable energy generation in urban areas

Theme 3 Developing healthy, sustainable and affordable transport systems	
Importance to New Zealand	The design, implementation and promotion of healthy and sustainable transport systems in New Zealand that allow for the basic access needs of individuals and communities to be met in a safe and environmentally sound manner is fundamental to fostering a connected and sustainable society. Unnecessary use of private cars places significant costs on society in the forms of pollution (air and noise), energy depletion, congestion, sprawl, community severance, inequity, and climate change (about one-third of greenhouse emissions are caused by private car use). Improving New Zealand's transport systems, which are unique to us due to our "long and skinny" geography and population distribution, would be of major benefit to the country.
Research components	• The development of a more sustainable system must minimise consumption of non-renewable resources, limit emissions and waste, reuse and recycle its components and minimise land use and the production of noise. It must be affordable, efficient, offer choice of transport mode and offer equity within, and between, generations. • This Theme would draw upon a raft of New Zealand and international expertise (e.g., in economics, design, engineering and injury prevention) and new technologies (e.g., intelligent sensors to monitor traffic flow in real time).
Theme 4 **Maximising social connectedness**	
Importance to New Zealand	New Zealand's cultural and geographical uniqueness brings with it specific challenges that cannot be addressed elsewhere in the world.
Research components	• Questions about the success (or lack of it) by which Māori have adapted to urbanisation remain largely unaddressed. Understanding the role by which iwi with Treaty settlement resources can more successfully contribute to urban development, finance and governance in New Zealand is critical in this respect. • New Zealand's highly dispersed rural communities, also creates significant issues in terms of effective provision of services. The provision of healthcare to rural/remote communities (including GPs, dentists, specialists, physiotherapy, pharmacists), specialist services (e.g., large animal veterinarians) and ICT connectedness remain significant challenges, but ones that must be overcome given the high dependency of New Zealand on the sustained health and productive capacity of its rural sector. • New models of designing and delivering such services are required, including investigating how new technology platforms can be deployed to enable more effective remote service delivery.
Research Gaps and Opportunities	New Zealand is well geared towards delivering upon this Challenge. For example, the New Zealand Centre for Sustainable Cities is a multi-disciplinary research group that was established by the Tertiary Education Commission in 2008. The Centre in turn grew out of He Kainga Oranga/Housing and Health Research Programme, which has been funded by the Health Research Council for 12 years. The Centre is based in the University of Otago, Wellington and links Auckland,

	Massey, Victoria and Canterbury universities with NIWA and Landcare, as well as with city councils. Its strengths have resulted in them being designated as a Centre for Research Excellence by the University of Otago. In 2012, the Centre started the Resilient Urban Futures programme which considers cities as urban systems. The Centre would be supported with expertise in injury prevention, public health and energy research from around New Zealand. The collaborative nature of the Centre, and its extensive end-user engagement, also means that deliverables from this Challenge would be rapidly implemented.
Comments	Cities are the locus of most economic activity in New Zealand and worldwide, so the efficiency with which cities work matters for living standards. Cities are also the source of innovation for the future economy, which will be based around resource efficiency and decarbonised buildings and infrastructure. Given the complexity of cities, it is important to reduce the risk around unnecessary or unanticipated infrastructure investment, which can lead to increasing debt burdens and missed opportunities for innovations associated with smart, sustainable and resilient infrastructure. Since cities are also where most New Zealanders live (87%), the quality of life in cities is vital for health and social and cultural well-being. There are increasing community expectations for improved city liveability, with access to high-quality affordable or social housing an increasingly important requirement. Environmental quality and amenity access affect the quality of urban living, cultural values and activities, as well as inward investment, land value and productivity. The design and use of transport and the built environment are also key areas for reducing carbon emissions to mitigate climate change and reduce the vulnerability of cities to volatility in oil prices. Moreover, in New Zealand we have “long and skinny” energy distribution and transport networks that make whole-of-system planning vital. The precariousness of current electricity supplies were demonstrated in 1998 after one of the main electricity lines going into Auckland overheated, leading to a major cable failure, resulting in a five-week-long power outage in the central city. The electricity blackout in Auckland in 2006, after the failure of an Otahuhu substation, led to further huge disruption in business activity. In addition, the aftermath of the Christchurch earthquake has shown that earthquakes can have devastating impacts not only on citizens and their institutions, but also on the physical infrastructure, such as electricity cables and water and sewer pipes. However, the imperative to rebuild Christchurch has highlighted one of the major science challenges: how can we apply our scientific knowledge to rebuilding an intelligent, smart city for the twenty-first century?

Entry ID	450
Smart, Safe, Sustainable Cities - Rebuilding Christchurch and Beyond	
Theme 1 **Improving the Economic Development Potential of New Zealand Cities**	
Importance to New Zealand	The government has three main priorities in addition to the overall challenge of returning New Zealand's economy to fiscal surplus: (1) building a more productive and competitive economy; (2) delivering better public services within tight financial constraints; and (3) rebuilding Christchurch. Principal among these is the economic goal to build a more competitive and productive economy. We want our existing businesses to succeed and become more profitable. We need to attract innovators, investors, business, visitors and residents. We need smart liveable cities to compete internationally in attracting a highly skilled workforce. We need better public services and a business friendly culture. We need an ICT infrastructure, research and development systems and creative innovation networks – this is the kind of infrastructure a city needs to support creative and knowledge-intensive economic growth. Post-earthquake Christchurch is now generating significant economic development opportunities from multiple and diverse rebuild initiatives and stakeholders. This is improving the regional innovation system through strengthening collaboration, particularly between research institutions and business, developing sector precincts, and building management capability and entrepreneurship skills. However there are few systems to connect the core economic development concepts of innovation, workforce talent and natural wealth within the city to support a smart, sustainable, long term economic growth. The city is starting to develop limited cross sector growth initiatives, such as the Canterbury Regional Innovation system, but is still struggling to connect the city's innovation eco-system and help create opportunities for both collaboration and commercialisation of ideas. A systematic economic growth model is needed. "
Research components	(1) Business economy: Understanding the natural wealth and distinctiveness of New Zealand cities and what is needed to create a compelling framework for investment and attracting high value skills. Identifying barriers to developing a business friendly environment. (2) Building Innovation: Creating a living lab for identification of creative, local-market-specific innovations that resonate with city leaders and constituents. User driven research and innovation supported by strong links to education and research organisations. (3) Labour market: Understand drivers to attracting highly skilled people, and more people with the skills to develop, manage and grow business, underpinned by strong networks and alliances between business, education and research

	organisations. (4) Data Collection and Connectedness: Enabling real-time interaction to facilitate decision-making based on the data produced. In the system of systems that is a city, the potential for efficiency grows as more data is obtained through sensors and more systems interconnect and interact and it is also an enabler and source of innovation for entrepreneurs. (5) Digital services: Development of new services adding value to eGovernment data, crowd sourcing innovation, the physical infrastructure interfaces with digital systems, and integrated city services for which the interdependencies of the various city subsystems create a significant scientific and engineering challenge. (6) New technologies and their application in cities: Ultrafast broadband and information technology can play a central role in smarter cities by supporting awareness through instrumentation (sensors), interconnection, and intelligence in areas ranging from efficient city infrastructure and eGovernment services to environmental protection and the operations of commercial enterprises.
Theme 2 **Strengthen Community Resilience, Safety and Wellbeing**	
Importance to New Zealand	Rapid urbanisation in New Zealand cities is turning issues such as public safety, healthcare, education, and housing into significant challenges. There is a need to reduce long-term benefit dependency; support vulnerable children; increase participation in education, lift educational achievement training and employment for all; prevention of family violence; and greater recognition of the contribution of older people. The social wellbeing of communities and individuals depends on a range of factors, including access to quality housing, transport, education and health systems and inclusive communities, which support people to participate fully in the life of the region. The government has set specific targets to ensure best possible value is achieved from spending on public services and associated critical infrastructure. Many of these key result areas are in the social sector areas of housing, healthy living, education and social services. These key result areas must be viewed holistically in order to make a city liveable, taking a long term view in looking after people, promoting social cohesion and stronger relations between diverse ethnic, cultural and religious communities, demographic change, wellbeing and participatory governance. In the Christchurch recovery, government and non-government health and social service providers are providing assistance and investigating how to reorient services in the earthquake context and how to reach out to people in need. When agencies collaborate over social and public health recovery, they can provide services more efficiently, improve public health outcomes and build the resilience of communities for the future.
Research components	(1) Decision making: Tools for eGovernment, crowd sourcing and use of ICT for participation and engagement inside communities to promote social cohesion and build a strong, thriving and inclusive society.

	(2) Education: Use of evidence based practices to equip New Zealanders with 21st century skills so all school leavers have the skills and knowledge to gain sustainable employment, pursue further education, contribute to society and become leaders and innovators. (3) Health: Determine how the characteristics of local neighbourhoods and lifestyle can positively influence health outcomes reduce health inequalities experienced by disadvantaged groups and health related behaviours. (4) Children and young people: Comparative studies of children and young people's lifestyles, measuring their wellbeing, energy use, aspirations and use of, and access to new technology platforms for communication, education and leisure. (5) Community planning: The development and design trajectories embarked on with respect to creating smart, safe and sustainable spaces benchmarked internationally. (6) Māori: Enhancing urban development with Māori philosophy a.) Intergenerational; b.) Partnership driven; c.) Absolute commitment to the region; d.) Consensus based (7) Housing: Understanding the impact that healthy homes have on health and wellbeing. Determining how best to meet needs for improved access to affordable quality housing. (8) Public Safety: Moving emergency services to broadband to enhance the effectiveness of public safety, disaster response, better communities etc. Safeguarding utilisation of public and privately gathered data and eGovernment and critical infrastructure. Developing intelligent policing to reduce crime in our communities and improve safety and wellbeing through partnerships with the community."
Theme 3 **Built Environment / Accessible Cities**	
Importance to New Zealand	The opportunity exists within an estimated $30 billion of investment in the Christchurch rebuild and another $40 billion of investment in the Auckland urban plan for the research sector to make a significant contribution to the understanding, design and growth of our future cities. Evaluating and contrasting the best practises used overseas and developing new technologies for 'sensor'-ed cities to develop highly connected, efficient, safe and resilient cites. Important objectives include enhancing the spiritual, spatial and sustainable qualities of our built environment through the adoption of the best models in regenerative urban design. Incorporate community vitality and quality-of-life objectives by protecting intergenerational environmental values within the built environment. Building infrastructure that is adaptable to our changing needs, resilient to hazards, climate change. World-class integrated transport systems, inclusive compact cities, economic powerhouses providing jobs for all our people and protection for our built and natural environment.

	As the Christchurch city is being rebuilt, we can build in a lot of technology which would be uneconomical to retrofit into existing cities. This is a unique opportunity for innovative work in this area both for developing as buildings are being erected, roads are being dug up for new services, and major new public facilities (such as transit hubs) are being designed and constructed.
Research components	(1) Built Environment: Development of a safer New Zealand building practice utilising superior materials and technology suited to New Zealand conditions. (2) New Technology: Developing interoperability between sensor networks, integration of systems and servicing people. Harnessing the huge proliferation of data. (3) Energy Security: Incorporating our understanding of changing energy supplies and energy efficiency technology in future proofing the built environment (linked to 'Energy' challenge proposals) (4) Hazard Resilience: Incorporating our understanding of changing society and physical the environment in future proofing a safe built environment (linked to 'Hazards Resilience' challenge proposals) (5) Simulations, Prediction and Modelling: Create city modelling frameworks for integrated planning across many building, transport and other infrastructure simultaneously (6) Resources: Determining environmental limits and integrating management of these natural resources e.g. water and waste (linked to 'Water' challenge proposals) (7) Land Use: Understanding the dynamic nature of that part of the natural environment that has been integrated into built environment (flood banks, rivers, the estuary and coastline). (8) Food security: Determining the extent of a city's dependence on global food supplies and how much food is locally grown. Understanding existing food sources. Identifying risks to the current urban food system identifying the minimum requirements of a city to ensure long term food security. (9) Transport: Future road and highway networks, railways, mass transit systems and transport terminals. Providing for pedestrians, cycles, public transport and private vehicles; speed zones and streetscapes; parking; service vehicle requirements that work well with the buildings and public spaces to create great places.
Theme 4 **Regional Growth and Development**	
Importance to New Zealand	Capitalising on the complementary strengths in cities and rural surrounds for mutual gains in sustainable economic development. Primary production accounts for 50 per cent or $25 billion worth of New Zealand's exports, and that income is generated by 35,000 farmers. Urban dwellers have become increasingly remote from the countryside, with less and less in common

	with their rural counterparts. Fewer people now have an understanding of farming and what is involved in producing the food they eat and the value of primary production to the national economy. Urban people still understand the economic importance of agriculture, but many have concerns about its environmental impact, which has in turn affected public perceptions of farming and farmers. They are also often better represented among the ranks of the planners, politicians, and other holders of instruments of power creating concerns about representation. Where should governments and business invest their resources? Should it be in the often poverty-stricken, depopulating rural areas, or in the burgeoning urban areas where development of infrastructure services struggle or fail to keep up with the needs of the incoming population. The issue becomes more one of working out how to maximise the opportunities that these investment opportunities represent. Rural areas should not be developed to the exclusion of struggling urban areas, and vice versa. Each community has its own needs, and adaptive capacities, whether social, economic, environmental, or cultural. And each has a contribution to make to the well-being of the region and the nation.
Research components	(1) Regional Economy: How can a smart city support rural productivity for a prosperous region? How to attract more people with skills to develop, manage and grow rural business? How can these needs be addressed to combat issues of urban drift and underemployment to rebuild sustainable rural communities? (2) Urban/rural dependencies: Rethinking the relationship between cities and their rural environs considering the overall footprint of a city: pollution, particularly water; resources, particularly food; transport to/ from the city. (3) New Technology: Understanding the differing technology needs in rural communities. Encouraging agri-technology benefits and bridging the rural digital divide. (4) Education and Health: Social issues, especially accessing education and health in isolated rural communities. (5) Community Planning: Community stability in the face of changing demographics, such as the influx of life-stylers into traditional farming areas. Alternative technologies and funding models to support the high costs of dispersed infrastructure and lack of economies of scale. Rebuilding rural communities decimated by years of farm amalgamations and urban drift. (6) Land use: Rural issues related to natural resource and environmental management, the servicing and sustainability of small communities, and debates around hot issues such as irrigation-based farming in New Zealand, erosion and flood-plain management, sustainable tourism, managing indigenous biodiversity and water quality and changing land use due to climate change. "
Research Gaps and Opportunities	Theme 1: New Zealand cities need to understand the increasing complexity in their populations, as demands are increasing around quality of life expectations with respect to city infrastructure, amenities and natural resources as well as developing the infrastructure needed to support quality knowledge-sector jobs and industries. This is occurring alongside contradictory pressures to reduce

	resource use (to contribute to environmental goals), lower costs to residents of running the city (as a result of economic downturn) and the need to become more internationally connected and export-driven to compete globally for investment and high skill labour. The challenge for New Zealand cities are to gather good data in timely, cost-effective and efficient ways understand these complexities (including global factors) and find solutions which will make New Zealand an attractive destination for investment and high skill labour. For instance Christchurch Development Corporation has identified the need to address key questions around competitive differentiation, leveraging and creating core infrastructure, investment, enhancing the talent present in its workforce and addressing weaknesses in the tools and processes it has to collectively manage this ecosystem . Canterbury Earthquake Recovery Authority has also released a programme of twenty projects as a foundation for the economic recovery of Christchurch. Local research is needed to address this complexity supported by international networks and models. New technologies are needed to improve 'intelligence' on how the city operates (and, importantly, how people operate within it) and improve the efficiencies in city infrastructure, amenities and natural resource use. Theme 2: Urban performance currently depends not only on the city's endowment of hard infrastructure ('physical capital'), but also, and increasingly so, on the availability and quality of knowledge communication and social infrastructure ('intellectual and social capital'). The latter form of capital is decisive for urban competitiveness. Providing research support for integrated and community-led initiatives can help people cope with stress and uncertainty, as well as minimizing potential hardship, inequity and unnecessary disruption to housing, education and health services. Keeping abreast of best practice evidence from around the world to provide evidence based solutions underpinning build community resilience, confidence and leadership so local communities can play a key role in recovery; strengthen and support existing collaborative initiatives within greater Christchurch; engage directly with greater Christchurch communities, including iwi, to encourage widespread participation in the planning and implementation of recovery; support the development of local neighbourhood plans and initiatives to help build stronger neighbourhoods. For example the social priorities in Christchurch are to strengthen community resilience, safety and wellbeing and enhance quality of life for residents and visitors by: (1) enabling and empowering local communities to shape and lead their own recovery; (2) growing capacity, knowledge and skills within the community to build resilience; (3) delivering community, health, education and social services that are collaborative, accessible, innovative and inclusive; (4) supporting people, in particular those facing hardship and uncertainty, by providing quality housing, education and health services; and

	(5) supporting communities as they go through the processes of resettlement. Theme 3: All major New Zealand cities are coastal – 75% of us live within 10 km of the coast. The Christchurch earthquakes have demonstrated how vulnerable our coastal infrastructure, habitation and amenities are while Auckland demonstrates what an economic and recreational boon living by the coast can be if we get it right. How do we do this and at the same time protect our major cities from expected sea level rises over the next 50 or so years? There is a growing need for cities to improve the way they monitor their public infrastructure, such as transportation, buildings and structures (e.g. bridges), security, energy distribution, water distribution, waste management and communication networks with most of the administrative bodies operating independently, with dedicated IT systems and limited information overlap. Just as physiological sensors can vital provide information about the health of the body, new technologies can be used to provide near real time health of a city and its infrastructure. An example of this is the 'sense-able' city - a combination of widespread sensor networks, highly connected buildings and people, and ubiquitous mobile devices combined together (http://senseable.mit.edu/). Much like a living lab the sensing city will attract high value businesses with applicable technology and trigger further innovation, integration and efficiency. Theme 4: The urban rural connection is interesting from a research perspective, as there is so much concentration across the world at the moment on smart cities, but relatively little looking beyond the city. Given New Zealand's population distribution and economy with a particular focus on agriculture and primary produce, we need to look beyond the city to understand the complex interaction between the city and the hinterland which supports the city. New Zealand may be one of the best places in the world to study Smart City + Smart Agriculture. A fundamental difference between urban and rural planning is the levels of awareness of the importance of natural systems and processes. Urban dwellers are more likely to feel nature is under control, while rural dwellers are more likely to respect or be wary of nature. Both, however, live with risk and uncertainty. Finding ways of fostering shared modes of thinking between these two camps, especially about risk, is crucial for ensuring that rural development is sustainable. And it is not just the people that we are concerned about. Sustainable development in rural areas demands sustainable patterns of land use, sustainable use of water resources, management of soils and soil erosion, and so on. The health of the land and the people must be considered as a part of the same question. Similarly, urban development has to consider pressures on local ecosystems, and the potential for ecological rehabilitation in areas that have become degraded through poor or inadequate infrastructure.

Entry ID	465
Creating positive urban futures	
Summary	The goal is to make both urban and rural New Zealand more liveable. Themes include designing homes, neighbourhoods and communities that are efficient in resource use and resilient to natural hazards; and social and demographic change, integrating efficient energy and infrastructure that is resilient to technological change and natural hazards into urban areas; developing affordable, healthy, sustainable, environmentally sound transport systems as an alternative to the unnecessary use of private cars; improving iwi contribution to urban development, finance and governance; and developing new models to improve effectiveness of provision of services to rural communities
Theme 1 **Building cities as resilient, replenishing systems.**	
Importance to New Zealand	As the population becomes increasingly urbanised, there is a need for cities to provide a sense of place, and to be sustainable and replenishing systems. This is a global challenge which is particularly relevant to New Zealand given 85% of our population already lives in urban settings, a trend which is projected to increase. If we get it right in our cities, New Zealand will prosper
Research components	• Component 1: Identify possible economic, environmental and social 'shocks' based on trends and projections, develop modelling tools for predicting responses and test against a variety of policy interventions, utilising 'big data'. • Component 2: Develop low impact energy generation, transmission and storage solutions. Develop true zero waste solutions, including the exploration of generating energy from waste. • Component 3: Innovate around the creation of low impact and affordable products for transport and housing to transform affordability and quality of life. • Component 4: Understand how cities grow and evolve, including the role regulation, transport systems, property development, housing market demand and supply, and incentives play. Develop interventions that will enable New Zealand to create cities which are prosperous, efficient, healthy and safe. • Component 5: Investigate food production options that have a low environmental impact.
Theme 2 **Growing our natural capital to underpin economic growth, social wellbeing and environmental health.**	
Research components	• Component 1: Investigate tools and techniques to ensure that New Zealand becomes and remains pest free to the benefit of conservation, agriculture and horticultural practise. • Component 2: Identify cost effective techniques for urban development which retain and restore water quality, including net positive energy desalination, as well as tools for water conservation. • Component 3: Develop tools to properly value Ecosystem Services and create effective interventions and incentives to improve our natural capital.

	• Component 4: Investigate opportunities for business and job creation from the natural environment, including the natural urban environment.

4 Society and Culture

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

Table 4: Summary of proposed challenges and themes

Entry Id	Challenge	Themes
48	Supportive, creative and diverse communities.	Local communities are supportive of their members, encompassing social and cultural diversity and able to facilitate creative solutions to local issues.
92	A gross happiness index to add a further dimension land review the concept of GDP in economic planning	Improve the delivery of good government and standard of living
240	To develop a risk management strategy to optimise New Zealanders' well-being if, because of external factors, New Zealand experiences very low economic growth for a sustained period	1. Understanding what international circumstances might mean that, despite best efforts domestically, significant economic growth (GDP/capita) cannot be achieved in New Zealand for a sustained period, and understanding the likelihood of those circumstances occurring 2. The goal of this theme is to understand the risks to New Zealand society if, despite best efforts domestically, significant economic growth (GDP/capita) cannot be achieved in New Zealand for a sustained period 3. The goal of this theme is to understand how to best manage the risks associated with very low economic growth (GDP/capita) in New Zealand over a sustained period 4. The goal of this theme is to identify the key elements of an operational framework comprising a risk-response plan, a monitoring plan, a communication plan and an implementation plan
278	Supporting a thriving and productive New Zealand: Maintaining high levels of material and subjective wellbeing requires scientific approaches that underpin responsive and tailored policies that respond to a dynamic and changing economy and society	1. Our changing economy: To guide investments in assets such as skills, knowledge, technologies and infrastructure, to enable us to maintain material standards of living, while adapting to new opportunities and constraints, for current and future generations 2. Our changing society: To stay ahead of changes in the society's structure and functioning. Rigorous research will enable us to tailor policies to remain effective in the face of change, and to continue advancing the aspirations of its members
292	To enhance the role of human	To enhance the role of human capital in New

	capital in New Zealand's economic growth	Zealand's economic growth
325	Fostering an innovative and cohesive New Zealand culture	1. Participation and cooperation 2. Innovation and adoption 3. Diversity and cohesion
341	To develop culturally responsive science teaching (CRST). Using the cultural knowledge, prior experiences, frames of reference, and learning approaches of ethnically diverse students to make learning encounters more relevant and effective for them	1. Develop teachers' knowledge base about ethnic and cultural diversity in science classrooms, i.e., teachers' as cultural brokers 2. Develop collaborative and active partnerships of teachers, students and scientists in science teaching and learning, i.e., scientists' as cultural brokers
364	For New Zealand to have the cleanest water, safest food, least communicable disease in the world, thereby be the best place in the world to live	For New Zealand to have the cleanest water, safest food, least communicable disease in the world
386	Building a flourishing e-Society	1. Inclusiveness of the future digital society 2. Combining Carbon Neutrality with economic growth through information technology 3. Getting the right information to the right people at the right time 4. Make information technology a driver of quality
416	Scientific, Technological, Engineering and Mathematical contributions which assist New Zealand to better compete in the Global Market Place	To develop measures to evaluate and direct, and new initiatives to implement, ways in which STEM can assist New Zealand to better compete in the Global Market Place
472	Nurturing tomorrow's citizens today	1. Improved understanding of society as a whole 2. Improved understanding of families/whanau 3. Understanding childhood development

Entry ID	**48**
Supportive, creative and diverse communities	
Summary	This goal of this proposal is to develop resilient and inclusive communities, which are supplied with the means to find and devise solutions to local problems. A variety of approaches must be sought in order to do this, each tailored to the unique dynamic of specific communities, and incorporating aspects of community-lead development (both asset and economic based) and social enterprise. Developing these approaches will include critical evaluation of current government policies.

Theme 1 **Local communities are supportive of their members, encompassing social and cultural diversity and able to facilitate creative solutions to local issues.**	
Importance to New Zealand	Geographic communities and communities of interest are the basis of our society and create our shared sense of identity. Flax roots development is the most effective way to build creative, inclusive and resilient communities. It is important therefore that communities are provided with the resources and power to utilise those resources in ways they see fit, in order to find local solutions to local problems. Such activity also promotes participative democracy. Government must understand that there is no correct way to do this, it may come from one or more of the following approaches: community led development, community development, social enterprise, social action, community economic development, asset based development, TLA's community outcome planning, self-help support, sustainable development, Iwi development, community recreation planning, community arts, neighbourhood development, building social capital or strengths based development. All these methods seek to develop communities that are inclusive, creative and supportive to its members. This is important in times of hardship or disaster. Recent events such as the Pike River disaster and the Christchurch earthquakes have evidenced the benefits and highlight where this was lacking. The 'heroes' of both of these events were not the government or local authorities but the citizens that banded together to help and support each other.
Research components	We need to understand the nature and diversity of our communities in all their forms, geographic, cultural, social groupings, by disadvantage or other. Community members will likely have affiliation to a number of communities and as such understanding how these communities interact across informal and formal groupings is an important key to forming government policy related to wellbeing and identity. Research that seeks to understand the many forms of community development is useful to ensure that a 'one size fits all' is not adopted. To critically review current government policies and initiatives with a community orientated lens e.g. the charities commission, the community government compact, funding and contracting administered by the Ministry of Social Development. From this we can investigate the most appropriate actions government can take to facilitate and resource (regulatory, funding & support) community activities that firmly locate the decision making and accountability with communities themselves rather than with government or their agents.
Research Gaps and Opportunities	We need to understand the nature and diversity of our communities in all their forms, geographic, cultural, social groupings, by disadvantage or other. Community members will likely have affiliation to a number of communities and as such understanding how these communities interact across informal and formal groupings is an important key to forming government policy related to wellbeing and identity.

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Entry ID	**92**
A gross happiness index to add a further dimension land review the concept of GDP in economic planning	
Summary	This challenge proposes a research programme into developing a national happiness index for use by planners and government to improve standard of living
Theme 1 **Improve the delivery of good government and standard of living**	
Importance to New Zealand	Lifestyle is a major attractant to New Zealand and highly valued and not material standard of living alone. The environment, lack of overcrowding, access to education, government and influence, are taken for granted. We have been a mostly exploitative economy and this has benefited the few. Economics has shortcomings but is the main advisor to government and planning agencies. GDP is a limited concept being reviewed around the world now; it is overly concerned with what we have considered as measurable, but we can now measure happiness.
Research components	Historical context. Establish indicators and a measure of happiness. Propose an index and systems for planners and government. Collate offshore results and research in this area and propose legislative changes.
Research Gaps and Opportunities	In recent years neuroscience and psychology of happiness or positive psychology have made progress in establishing a scientific basis for happiness. Economics did not forecast the Global Financial Crisis and frontier economics is questioning many assumptions of orthodox economic theory. IN a world with diminishing resources economics is failing planners.

Entry ID	240
To develop a risk management strategy to optimise New Zealanders' well-being if, because of external factors, New Zealand experiences very low economic growth for a sustained period	
Summary	The goal is to develop a risk management strategy to optimise New Zealanders' wellbeing in the case of a sustained period of very low economic growth. Themes include identifying the possible types and likelihood international events/ circumstances that may cause a sustained period of low economic growth in New Zealand, understanding both economic and social implications of a sustained period of very low economic growth, identifying possible government, business and community responses to a sustained period of very low economic growth and understanding societal preferences towards possible responses, developing an operational framework comprising a risk-response plan, a monitoring plan, a communication plan and an implementation plan for a sustained period of low economic growth
Theme 1 **Understanding what international circumstances might mean that, despite best efforts domestically, significant economic growth (GDP/capita) cannot be achieved in New Zealand for a sustained period, and understanding the likelihood of those circumstances occurring**	
Importance to New Zealand	This theme is important because it assesses the magnitude of the risk of plausible future international developments constraining New Zealand's growth in GDP per capita to very low levels for the next decade or so.
Research components	Research Component 1.1: (i) Identifying what possible international developments might lead to very low economic growth internationally over a sustained period, say more than 10 years (high national debt to GDP ratios, continued de-leveraging of economies after the 2008 Global Financial Crisis, high energy prices, high prices and/or physical shortages of other critical raw materials, coping with the adverse effects of climate change, fiscal problems and possible break-up of the Euro Zone, United States failing to satisfactorily resolve its fiscal situation, Global Financial Crisis Mark II and subsequent de-leveraging); and (ii) Assessing the likelihood of such developments occurring. Research Component 1.2: Understanding the macro-economic implications for the New Zealand economy of very low economic growth internationally (continued low economic growth in Europe and the US, lower economic growth in China and hence Australia) for more than, say, 10 years at a time when New Zealand is also having to invest to adapt to climate change. This would examine the effects on aspects of the economy such as the inflow of capital from overseas, return on investment, interest rates, gross capital formation in total and in different sectors, volume and value of exports, exchange rates, terms of trade, and ultimately on New Zealand's rate of economic growth (GDP/capita).

Theme 2 **The goal of this theme is to understand the risks to New Zealand society if, despite best efforts domestically, significant economic growth (GDP/capita) cannot be achieved in New Zealand for a sustained period**	
Importance to New Zealand	This theme is important because it will identify new, or intensified, points of tension and conflict in New Zealand society and begin to identify societal preferences for different possible outcomes in the context of sustained very low GDP/capita growth in New Zealand. It will do this by: (i) identifying the economic and social (including cultural) implications and pressures likely to result from a sustained period of very low growth in GDP/capita in New Zealand; (ii) improving our understanding of the relative importance New Zealanders would place on mitigating each of the identified issues; and (iii) investigating societal preferences between different possible outcomes.
Research components	Research Component 2.1: Understanding the macro- and micro-economic implications of very low GDP/capita growth in New Zealand over a sustained period for the way we currently do things (gross capital formation in total and in different sectors, private sector debt financing, productivity, income per capita, central government revenue and expenditure, local government revenue and expenditure, R&D funding and expenditure, differential sectoral growth rates, asset values, wage levels, employment, inflation, private consumption/capita, interest rates, etc.). Research Component 2.2: Understanding the social tensions likely to arise in New Zealand society as a result of very low GDP/capita growth over a sustained period (coupled with an aging population with its current expectations of levels of health care and National Superannuation) because expectations are no longer able to be met or because of perceived increases in social inequities. Research Component 2.3: Understanding the weightings that society, and selected sub-groups within society, gives to these risks and investigating societal preferences for different potential outcomes in a New Zealand experiencing very low growth in GDP/capita over a sustained period.
Theme 3 **The goal of this theme is to understand how to best manage the risks associated with very low economic growth (GDP/capita) in New Zealand over a sustained period**	
Importance to New Zealand	This theme is important because it will help to identify relevant trade-offs, and develop, and help to discriminate between, alternative policy-response packages designed to optimise New Zealanders' well-being in a situation of sustained very low growth in GDP/capita.
Research components	Research Component 3.1: Understanding what aspects of their lives different groups of New Zealanders would most like enhanced in a situation where

	increases in material consumption are severely constrained. Research Component 3.2: Identifying, or developing, measures of societal success and well-being that adequately reflect New Zealanders' preferences as revealed in 3.1. Research Component 3.3: Identifying possible different government, business and community responses (in substance and timing) to very low economic growth (GDP/capita) over a sustained period and understanding the social and economic implications of each.
Theme 4 **The goal of this theme is to identify the key elements of an operational framework comprising a risk-response plan, a monitoring plan, a communication plan and an implementation plan**	
Importance to New Zealand	This theme is important because it will inform policy-makers about what would be required to ensure that appropriate action would be taken at the appropriate time.
Research components	Research Component 4.1: Developing a risk-response plan that would set different levels of risk and appropriate actions to be taken at each of these levels of risk. Research Component 4.2: Identifying the key elements of a monitoring plan that would identify the nature and timing of monitoring required to adequately assess the level of risk at appropriate intervals. Research Component 4.3: Identifying the key elements of a plan for communicating with the nation as the assessed level of risk of a sustained period of very low growth in GDP/capita changed. Research Component 4.4: Identifying the key elements of an implementation plan for each level of assessed risk.
Research Gaps and Opportunities	As far as I am aware, with the exception of Research Component 3.2, there is little current New Zealand research relevant to the themes and research components outlined above. Hence it is likely that, with the exception of Research Component 3.2, all of the research themes suggested above are research gaps and opportunities that, if addressed, could make a significant contribution to achieving the challenge.
Comments	I suspect that the reason why there is so little New Zealand research currently underway that would make a contribution to this challenge is that the challenge is not one that is part of conventional thinking about the economy and living standards. Conventional thinking is focussed on the important issues of how to enlarge the economic pie, create more jobs and manage distribution and equity issues, all within the economic growth environment of the world as we have known it - specifically, an average growth rate of the world economy for the 40 years from 1970 to 2010 of 3.5% per year. We know that in many respects the world of the future will not be the world we have known. However, there is seldom any discussion of whether a reduction in

	the long-term average growth rate of the world economy might be one of those changes. Yet there are current or likely future changes in the world that mean that there is a risk of precisely that: for example, declines in productivity, pressures on resources, global financial crises, unstable and adverse climate change, de-leveraging following unsustainable debt bubbles, fiscal crises in major economic blocks, a demographic profile that is changing to a higher proportion of older people. Given the existence of that risk, it is prudent to assess its magnitude and implications for New Zealand, and if it is found to pose a significant risk to the well-being of New Zealanders, to develop an appropriate national risk management strategy.

Entry ID	**278**
Supporting a thriving and productive New Zealand: Maintaining high levels of material and subjective wellbeing requires scientific approaches that underpin responsive and tailored policies that respond to a dynamic and changing economy and society	
Summary	The proposed research programmes include the following themes: (1) our changing economy - application of rigorous scientific methods to identify the impacts of existing and potential investments in a changing world, identify and evaluate the impact of investments and actions, and investigate the conditions under which they are most likely to be effective. (2) Our changing society: (to stay ahead of changes in the society's structure and function identify and analyse broad changes in New Zealand society, delineate the underlying nature and causes of the changes, to form and test credible hypotheses about the impacts of the emerging changes, and to develop policy and societal responses
Theme 1 **Our Changing Economy: To guide investments in assets such as skills, knowledge, technologies and infrastructure, to enable us to maintain material standards of living, while adapting to new opportunities and constraints, for current and future generations**	
Importance to New Zealand	The economy never sleeps. Our ability to sustain and improve material standards of living depends on our ability to adapt to changing circumstances, and to be equipped to take advantage of future opportunities. Decisions made today shape the options that we will face tomorrow. The research theme focuses on investments that have long term consequences, and that will shape our economic opportunities for many years to come. We cannot rely solely on international research to guide our decisions on what is needed for New Zealand to make the best use of its economic resources. Comparative research as well as New Zealand-focused research is needed to identify the distinct advantages that will underpin our future productivity and prosperity. The benefit of any single research endeavour under this theme is

	uncertain. The cumulative value of the research will be to provide a sound foundation for decision-makers – be they individuals, households, businesses, or various levels of government. Their choices will be based on a well-informed interpretation of current and recent trends, and with consideration of a range of likely future options and developments. The costs of not maintaining research momentum are potentially huge. Investment decisions made in the absence of sound underpinning research are likely to be ineffective and wasteful, or even counter-productive.
Research components	The contribution of scientific research to this theme is through the application of rigorous scientific methods to identify the impacts of existing and potential investments in a changing world. There are few 'laws' in social and behavioural sciences and economics. Skilled researchers are, however, able to identify and evaluate the impact of investments and actions, and investigate the conditions under which they are most likely to be effective. Research is also valuable in highlighting important policy and management issues and focus attention on pivotal decisions that will shape our future options. The following list shows some key issues on which social science research is able to shed light. The scope of research under this theme is more broad and diverse than the items listed. The choice of worthwhile projects will reflect the combination of relevance, availability of evidence, and amenability to rigorous testing. A) Investing in skills, knowledge and discovery • Education and training – providing skills for life and work • Changing nature of work B) Creating productive and innovative businesses • Management practices • Dynamics and effectiveness of business innovation, research, and development C) Serving future generations • Intergenerational equity • Savings and retirement trade-offs. There is a range of key influences that will shape our future investments. Scientific inquiry will be needed to support decisions in the light of changing economic pressures, including: • Changing energy and resource use • The changing role and growing importance of cities • Growing importance of International links

Theme 2 **Our Changing Society: To stay ahead of changes in the society's structure and functioning. Rigorous research will enable us to tailor policies to remain effective in the face of change, and to continue advancing the aspirations of its members**	
Importance to New Zealand	Advancing scientific knowledge under this theme is of relevance to all New Zealanders – who we are, who we wish to become, and how we navigate the trade-offs that we will need to face in order to continue as a well-functioning society. Serving the interests of our society is the foundation of our democratic political system. Policies to advance societal objectives of fairness and improved well-being need to be tailored to the needs and circumstances of different individuals and families. Social policy in particular gives effect to socially-defined obligations to share risks and promote opportunities for all. Identifying the causes of and effective responses to poor outcomes for particular individuals, groups, and regions is a vital contribution of research effort in this area. Given the huge public and community investments, the costs of misdirected efforts are potentially huge, and therefore the potential gains of improvements in our understanding and policy are also substantial.
Research components	Research under this theme must identify and analyse broad changes in New Zealand society. Spotting what is changing is only the first step. Scientific methods must then be applied to delineate the underlying nature and causes of the changes, to form and test credible hypotheses about the impacts of the emerging changes, and to develop policy and societal responses that continue to be relevant and effective. Key changes that would be central to this endeavour include: A) Responding to our changing identity • Bi-cultural / multicultural society • Circular migration and changing notions of attachment • Social capital B) Responding to changing family patterns • Household formation, dissolution, 'blended' families C) Responding to changes in demographic composition • The nature and implications of population ageing • Retirement • Growing (young) Māori population • Migration – international and within New Zealand D) Responding to changes in technology and society • Changing nature of work

	• Social media Key dimensions of interest: Societal changes have direct and indirect impacts on wellbeing and on New Zealanders' capability to maintain material standards of living. Change is also likely to lead to unequal outcomes, with some subgroups within society bearing a disproportionate share of the burden of adjustment. Research must shed light on the differential impacts on different groups and areas – identifying their determinants and means of influencing. • Group differences in outcomes: Gender differences; ethnic and cultural differences; outcomes for children • Geographic differences in outcomes: regional, inter-urban and intra-urban differences in outcomes, demographic structure, economic base
Research Gaps and Opportunities	A significant scientific opportunity is establishing representative household panel survey designed to underpin research. This would fill a huge gap in social science research infrastructure, and would be uniquely suited to monitoring emerging social changes and supporting sound empirical research to identify the underlying causes and impacts of change. It would represent a substantial investment in social science research infrastructure, providing a common resource for researchers across disciplines and interests, collecting household level data on a broad range of social and economic domains. To realise the full value of such an investment, the survey data must be easily available to researchers in New Zealand and overseas – the likelihood of making new scientific discoveries, identifying emerging trends, and gaining innovative insights is enhanced by openness to a large and diverse scientific community. Successful household panel surveys that have generated insights for both research and policy include HILDA (Australia), Understanding Society (UK), SOEP (Germany), and PSID (USA). See http://www.motu.org.nz/news-media/new_zealand_panel_survey_-_feedback sought for a fuller discussion. Research infrastructure investment lowers the cost of subsequent empirical research, and also raises the value of complementary qualitative and in-depth case studies, which will be vital for advancing social science knowledge. The availability of rich linked administrative data in New Zealand can support rigorous empirical studies of economic decisions and our changing economy. Statistics New Zealand's Integrated Data Infrastructure prototype (IDI) and business databases are rich by international standards, and their availability opens up opportunities for research that is focused on New Zealand issues as well as being internationally significant.
Comments	Meeting Science Challenges in social science and economics requires more than solving a specific challenge. Scientific knowledge must keep up with the constantly evolving world, and 'received wisdoms' must be critically tested and re-examined. A range of disciplinary insights need to be brought to bear, supported by inter-disciplinary dialogue and in some cases, interdisciplinary teams. There is a need not only for large research programmes that build broad insights, but also for smaller research projects that are more able to generate innovative insights.

Entry ID	292
To enhance the role of human capital in New Zealand's economic growth	
Theme 1 **Economic growth arises from an overlapping combination of natural, physical, financial and human capital, and technology. Of these factors, human capital is the least researched and yet may have the greatest potential for contributing to productivity growth. It would be incomprehensible for a national research portfolio to not allocate at least ten percent of its budget to research in this area**	
Importance to New Zealand	Longitudinal research on the factors that contribute to the accumulation of all forms of human capital in New Zealand, and how these are connected to the generation of economic wealth and wellbeing

Entry ID	325
Fostering an innovative and cohesive New Zealand culture	
Summary	This challenge is aimed towards fostering an innovative and cohesive New Zealand culture. Focus is placed on how to foster community/cultural co-operation, which can be used as a means to deal with a variety of challenges facing New Zealand (i.e. ecosystem management, sustainable use of ocean resources, climate change, and endemic disease). Fostering this co-operation will require the identification of cultural practices and values that promote (or hinder) innovation and social change development, and ensuring widespread adoption of institutional programmes which support these practices (or discourage them).
Theme 1 **Participation and cooperation**	
Importance to New Zealand	As a nation, New Zealand faces many challenges. These include the need to protect our delicate ecosystem, manage our resource-laden seas, tackle climate change and fight disease. Unfortunately, these issues cannot be addressed via technological quick-fixes. Rather, they are inherently problems of social coordination that will require a culture of positive participation and cooperation to solve. This theme will utilize new and existing research in the social sciences to understand and promote ways in which we can build social capital and work together to tackle the social, economic, and environmental challenges facing our nation.
Research components	• Identify the major challenges facing New Zealand that require cooperation on a national level • Identify factors within our families, communities, and schools that promote (or hinder) political engagement • Identify ways in which cultural norms and institutions can be changed to motivate participation and cooperation at the level of the individual, group and nation

	• Design tools and institutional programmes that encourage people of all ages (and from diverse backgrounds) to work together and solve the problems that uniquely face our country • Understand how political engagement and the desire to cooperate with others is shaped over the life span • Develop and implement institutional programs that foster the skills required of an informed (and politically-engaged) democracy • Identify ways of harnessing the strengths of families, communities, and the educational system in order to foster sustained engagement, co-operation and social responsibility • Identify (and remove) barriers to citizens' full participation in the public and community spheres so that all views are represented in Parliament.
Theme 2 **Innovation and adoption**	
Importance to New Zealand	New Zealand can be proud of its history as a world leader in social change and technological innovation. From our no. 8 fencing wire ingenuity to our world-leading stance on important issues such as women's suffrage and anti-nuclear proliferation, New Zealand's place in the world has been defined by our culture of social and technological innovation. However, recent declines in our social and economic standings relative to other OECD countries suggest that we may be taking our innovative culture for granted. If this trend continues, we risk losing our stake as world leaders in this domain. This theme will capitalise on new and existing research in the social sciences to understand and promote the emergence and spread of new ideas, behaviours and technologies. By understanding how New Zealand adapts to - and leads the implementation of - new ideas, we will be able to tackle the major challenges of the 21st century.
Research components	• Identify cultural practices, values and norms that promote (or hinder) innovation and social change by making comparisons across individuals, cultures and historical periods. • Understand how new ideas, behaviours and technologies spread through social networks by using contemporary and historical data. • Understand the role of institutions in promoting innovation and social change by studying the association between institutional structures, innovation and adaptation to emerging problems. • Design interventions and institutions that shift cultural practices, values, and norms in such a way that they promote innovation and change. • Create educational programmes that promote creative thinking among individuals and groups
Theme 3 **Diversity and cohesion**	
Importance to New Zealand	From even before the signing of the Treaty of Waitangi, New Zealand has been predicated on the fusion of two cultures. In recent years, however, an influx of immigration has changed the traditional makeup of our bicultural society. Thus, a central challenge facing New Zealand is to both reconcile and respect our historically-based biculturalism with the increasingly multicultural composition of

	our population. To achieve these goals, this theme will identify novel ways of meeting the unique challenges that face a multicultural New Zealand.
Research components	• Characterise how the cultural milieu has changed in New Zealand history, and how it is likely to change in the next 20 years. • Identify the ways in which people who exist outside of the traditional bicultural framework adapt to and understand life in New Zealand. • Identify factors that ease the transition between immigrants' home culture and the new culture they will encounter in New Zealand • Evaluate the strengths and weaknesses of past strategies used to reduce ethnic disparities • Identify ways of increasing the strength of social ties both within and among distinct communities. • Design strategies that promote a strong (and unified) New Zealand identity that is both accepting of new views and respectful of our bicultural heritage

Entry ID	**341**
To develop culturally responsive science teaching (CRST). Using the cultural knowledge, prior experiences, frames of reference, and learning approaches of ethnically diverse students to make learning encounters more relevant and effective for them	
Summary	This research proposes to develop science teaching methods which are culturally tailored and therefore of most effective with ethnically diverse students. This will require teachers to develop a cultural knowledge base, and the skills to incorporate this knowledge base into science-teaching activities. This will need a diverse and active collaboration to be fostered between teachers, students, and scientists.
Theme 1 **Develop teachers' knowledge base about ethnic and cultural diversity in science classrooms, i.e., teachers as cultural brokers**	
Importance to New Zealand	The goal of the research is to identify and develop in science teachers the knowledge and skills to incorporate and use multicultural information, resources, and materials to engage students in learning science. Teachers can contribute to culturally responsive teaching when they are capable of using a wide variety of instructional strategies that are informed by socio-cultural contexts and recognising the cultural heritage of different ethnic groups in their science classrooms. The rationale for doing the research is to study the effects of drawing on the vast resources that students of different ethnic groups bring to the science classrooms to support changes in teaching practices. The potential benefits for students: 1. Developing their positive self-concepts, knowledge of and pride in one's own ethnic identity, as well as their dispositions and attitudes towards learning

	science. 2. Students are held responsible for each other's learning as well as their own. They learn to be mutually supportive and internalise the value that learning science is communal, reciprocal, interdependent and collaboratively enriching. 3. Students are encouraged to participate actively in science discourses that are relevant to their cultures and experiences. The potential benefits for teachers: 1. Moving beyond a focus on exams and grades to make science lessons interesting and relevant to students. 2. Building their own knowledge base (knowledge about the cultural values, learning approaches, historical legacies of different ethnic groups as well as pedagogical content knowledge). 3. Reflecting and rethinking their own assumptions of cultural universality and neutrality in teaching and learning science, and how they relate to their students.
Research components	The main research components are: 1. Investigate the roles and responsibilities of teachers as 'cultural brokers' or being culturally responsive. 2. Research on New Zealand science teachers' knowledge base of culturally responsive pedagogy. 3. Study the 'voices' of students learning science in multicultural classrooms. 4. Develop, implement and evaluate strategies that support teachers in building and using culturally relevant science teaching practices in schools. 5. Develop, implement and evaluate assessment strategies that support CRST, especially at the junior secondary level.
Theme 2 **Develop collaborative and active partnerships of teachers, students and scientists in science teaching and learning, i.e., scientists' as cultural brokers**	
Importance to New Zealand	The goal of the research is to identify and leverage on the wealth of knowledge and skills that scientists bring to the science classrooms to support and improve CR teaching and learning. The rationale for doing the research is to study the effects of community of learners involving scientists, teachers and students within a CRT framework. This has potential benefits for New Zealand students: 1. Developing in students problem-solving techniques used in authentic learning situations and environments. 2. Learning the "cultural capital" of school success in science through role modelling (negotiating the science curriculum, strategies for coping and help-seeking, time management, study skills, career choices). 3. Introducing and providing opportunities for students to participate in science discourses – dialogues/ conversations, argumentations, discussions with scientists and professionals in science related industries.

	The potential benefits for Science teachers include: 1. Moving beyond a focus on exams and grades to make science lessons interesting and relevant to students. 2. Sharing and building their own knowledge base (e.g. knowledge about influence and impact of science beyond the classrooms). 3. Building a community of learners. The potential benefits for science professionals and scientists include: 1. Allows scientists to articulate broader societal values for their research. 2. Scientists gain access to professionals who have expertise in translating research approaches and results into programs, exhibits, and other resources.
Research components	The main research components are: 1. Investigate the roles and responsibilities of scientists as 'cultural brokers' or being culturally responsive in relation to science education. 2. Develop strategies that support teachers to work with scientists in building and using culturally relevant science teaching practices in schools.
Research Gaps and Opportunities	There is a need for on-going professional development of science teachers on CRST and how best to support this in schools.

Entry ID	**364**
For New Zealand to have the cleanest water, safest food, least communicable disease in the world, thereby be the best place in the world to live	
Theme 1 **For New Zealand to have the cleanest water, safest food, least communicable disease in the world**	
Importance to New Zealand	For those diseases spread via contaminated water, food or casual (non-sexual) contact, it is largely a government and society responsibility to ensure public safety. While individuals can take precautions, expect government to ensure that water safe to drink, food safe to eat. If not they expect government to tell them so they can take precautions. While much of the rest of the world will increasingly have to sterilise, radiate, chlorinate and take other steps to reduce disease risk, New Zealand should aim for a future where we can eat and drink natural products that don't need treatment because they are intrinsically and demonstrably safe. New Zealand has unique advantages afforded by our isolation, high standard of living, well established society and government, to be able to lead the world with the safest water, safest food and lowest rates of disease. Sadly this is not the case currently. Our rates of many diseases among the highest in the world. One strategy

	would be to try and ignore the problem – clinically increasingly able to identify causes of illness, combined with a trend toward greater impacts (death, long term sequelae such as kidney failure as a result of the combination of pathogen evolution and increasing susceptibility in the population). In the information world there's no chance that the public won't become aware of problems. A much better strategy would be to harness our scientific knowledge, literate public and political will to ensure water and food are safe, and disease minimal.
Research components	Key science need will be to find ways to achieve this that are affordable and publicly acceptable. Requires multidisciplinary approach. Need strong public health system using the latest scientific developments to track disease, identify causes and measure effectiveness of interventions. Need to design and refine the most appropriate system for New Zealand. Interventions need to be targeted appropriately. Scientifically evaluate options, develop new ones. Science underpinning this is rapidly evolving. New strategies in rapid detection use of genomic analysis which need to make use of. Break cycles of disease transmission. Smarter with minimising waste, reusing safely and treating effectively where needed.

Entry ID	**386**
Building a flourishing e-Society	
Theme 1 **Inclusiveness of the future digital society**	
Importance to New Zealand	Inclusiveness is a requirement of fairness and non-discrimination. An inclusive e-society can foster the cultural diversity of New Zealand. A large share of public life will take place online. If groups such as the elderly are left behind, this will directly impact their well-being and economic status.
Research components	Understanding barriers for groups that are underrepresented in the digital society Understanding usability issues from the perspective of groups that have special needs - Understanding and reducing negative behaviour around information technology - Using information technology to overcome disadvantages, for example by increasing mobility and mitigating handicaps - using e-learning to overcome differences in education.
Research Gaps and Opportunities	How can we move from mobile devices to mobile citizens and mitigate the health impact of the sedentary lifestyle in our modern society? - What are the fundamental barriers that cause the apparent low uptake of teleconferencing, and prevent us from reaping the promised carbon benefit of telework? - Software development creates fixed cost, and New Zealand as a small economy has disadvantages from fixed cost. How to make software development lightweight?
Theme 2 **Combining Carbon Neutrality with economic growth through information technology**	
Importance	Information technology is a fundamental component of almost every efficient

to New Zealand	technology. Achieving both, sustainable economic growth and near-carbon neutrality is of strategic importance for New Zealand as a member of the World Community. Information technology is using already a large share of resources. It must be put to use in order to reduce waste of resources.
Research components	- Bridging Distance: Enabling New Zealand to participate in the world economy easily with a low carbon footprint. - E-learning: how to make life-long learning a major use of information technology. - Making New Zealand a centre for green computing, e.g. with datacentres running on hydropower.
Theme 3 **Getting the right information to the right people at the right time**	
Importance to New Zealand	It is crucial for New Zealand as a modern economy and its exposure to risks that information systems fulfil their mission, do not cause damage and deliver the high responsiveness that can be expected today.
Research components	- Getting the right information to people: Prevent information system failures such as Novopay through advanced software architecture and better software engineering - Getting information to the right people: prevent information leaks such as the ACC kiosk problem, through new security technology. - Getting information to people at the right time: Ensure rural broadband, develop responsive systems that work even in emergencies - Dealing with big data through datamining and technologies such as image processing in order to achieve the goals of this theme - How to deal with information overload of the individual worker and citizen?
Theme 4 **Make information technology a driver of quality**	
Importance to New Zealand	Quality is a major driver of growth and economic leadership. Poor quality translates in wasted money and wasted resources. New Zealand ranks high in surveys related to quality of living, quality of education and quality of governance. The information technology should measure up to the high quality expectations of New Zealanders.
Research components	- Understanding how to reduce the failure rate in large IT projects - Understanding how non-functional requirements such as security and efficiency of software can be achieved. - Understanding how to build more efficient, more useable software. - Use mobility of applications as a quality attribute of the services delivered
Comments	This is a submission that grew out of intensive discussions in the Department of Computer Science at the University of Auckland. We welcome this initiative, and we are keen on staying involved. We are open for discussing mergers of this proposal with other proposals.

Entry ID	416
Scientific, Technological, Engineering and Mathematical contributions which assist New Zealand to better compete in the Global Market Place	
Summary	This proposal has a goal of encouraging New Zealanders to build more companies to compete in the Global Market Place through Scientific, Technological, Engineering and Mathematical contributions. The proposal suggests a programme of research to develop measures to evaluate and direct, and new initiatives to implement, ways in which STEM can assist New Zealand to better compete in the Global Market Place (analysis of national and international patents and publications, national and international linkages for New Zealand companies and boards etc.)
Theme 1 **To develop measures to evaluate and direct, and new initiatives to implement, ways in which STEM can assist New Zealand to better compete in the Global Market Place**	
Importance to New Zealand	• Providing New Zealand business with a framework of assessment, to evaluate their export competitiveness, and thereby to increase their chances for export success • Making New Zealand businesses more competitive • Encouraging New Zealand business to compete in the global marketplace • Guiding investment of New Zealand businesses in the global marketplace • Improving efficiency of New Zealand exporters and manufactures • Encouraging young New Zealanders to embrace the Global Market Place • Better linking specialists in the STEM disciplines to link with New Zealand industry • Improving the New Zealand economy, to the benefit of all New Zealanders • Providing general aims which will link different specialists in STEM disciplines
Research components	• Analysis of national and international patents and publications • Analysis of national and international linkages for New Zealand companies and boards • Derivation of relationships between activity in patent and paper publications, and innovation • Evaluating Innovation for New Zealand businesses • Statistics, especially large data sets, related to the global market place • Research components from all STEM disciplines relevant to the New Zealand and export market • New initiatives in New Zealand related to the KTNs introduced recently in Britain • Mathematics Study Groups for New Zealand business • Preparing New Zealanders for future places in the Global Market Place • Novel engineering designs, which promise disruptive opportunities for New Zealand exporters

Research Gaps and Opportunities	• We lack widely accepted measures to assess how innovation is being taken up by New Zealand firms • There is a significant under-investment by New Zealand industry in research. • There are no Mathematics in Industry Study Groups being held regularly in New Zealand • There is no Mathematics CORE currently in New Zealand • We do not fund Olympiad Teams to compete internationally (seen as elitist) • We do not have a national body to represent technologists – cant encourage excellence easily • We don't have a Knowledge Transfer Network structure in New Zealand Comments: We need to encourage New Zealanders to build more companies to compete in the Global Market Place, and to help new and existing companies grow, to compete in the Global Market Place. STEM is an important input to meeting these goals, and is worthy of a National Science Challenge.

Entry ID	**472**
Nurturing tomorrow's citizens today	
Theme 1 **Improved understanding of society as a whole**	
Importance to New Zealand	Understanding communities and patterns of population mobility; evaluating government interventions for education, health, social resilience; understanding community beliefs as to meaning of 'family/whanau'; understanding sources of inequalities of income adequacy, housing and health affordability, crime and substance abuse; understanding impacts of urban planning on communities and individuals' health, including scaling up pilots to roll-out to wider areas; understanding social constructs that result in escalation of entry to justice system and our high rate of imprisonment.
Theme 2 **Improved understanding of families/ whanau**	
Importance to New Zealand	Improved understanding of families/whanau to enable evidence base for interventions that improve competence and capability of family/ whanau members to deal with life stresses, promote productivity and strengthen relationships. Improving data sharing between agencies, improving statistical groupings/ identification of family /whānau/ iwi level connections to understand structures of family/whanau and internationalisation of families; dependency ratios (both young and elderly), multigenerational caring and the changing role of state versus family and whanau care; intergenerational transmission of disadvantage including foetal brain development and psychological factors; evaluating family programmes and

	interventions such as parenting courses; understanding how families and whanau access, and contribute to, help in communities; role and trends of volunteering; changing the economic analysis model to understand how families with complex and multiple stressors make decisions in chaos, rather than relying decision making in rational profit-maximising model.
Theme 3 **Understanding childhood development**	
Importance to New Zealand	Understanding childhood development within a family context – data on number and age of children in different family/whanau groups to understand variable lifecourse; understanding balance between prevention and treatment (in terms of government interventions); neuroscience of impacts of pregnancy conditions on mental health, heart disease, stroke; genetic and epigenetic transmission of mental illness and how to block intergenerational transmission of disease risk. Understanding decision-making in family contexts and how to optimise outcomes for children by evaluating and improving interventions aimed at adults; creating evidence base to support decision making at family, community and government level.
Grouping	Early life and Neonatal and infant health

5 Crime

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

Table 5: Summary of proposed challenges and themes

Entry Id	Challenge	Themes
210	In New Zealand refugees are believed not to integrate successfully. The goal is to identify factors within the Criminal Justice System which contribute to the unemployment and underpayment of refugees leading to addressing these issues	1. Understanding of the impact of Police discretion whether to uphold or to apply the Law in incidence involving refugees 2. Understanding the experience of refugees in courts 3. Understanding of the length of sentence afforded to refugees 4. Understanding to the services afforded to the family of the offender
423	New science, frameworks, approaches and tools are needed to ensure a sustained reduction in crime in the community and at the border. Our vision is of a New Zealand that is a safe place for all to live and prosper free from the social and economic costs of crime	1. Innovative and transformative research and new technologies will ensure New Zealanders are safe in their homes and communities. Scientific advancements will be made in the prevention, detection, recording and solution of crime which will lead to sustainably reduced crime rates 2. Understanding and communicating new knowledge derived from the analysis of information to others so that justice outcomes are understood and improved for all 3. The goal of this theme is create scientific solutions to maximise security at the border from a crime perspective. This includes identifying hazards entering and leaving the country and protecting New Zealand flora and fauna from illegal export 4. Addressing the complex problem of crime and harm from drug and alcohol abuse through integrating and applying “crime science” and “services science” as an innovative coupled science platform

Entry ID	210
In New Zealand refugees are believed not to integrate successfully. The goal is to identify factors within the Criminal Justice System which contribute to the unemployment and underpayment of refugees leading to addressing these issues	
Summary	The goal is to increase understanding of and improve outcomes for refugees in the New Zealand criminal justice system. Themes include understanding the

	nature and impact of police discretion in incidences involving refugees, investigating the factors that influence the experiences of refugees in New Zealand courts, understanding the factors that influence the length of sentences afforded to refugees, understanding the economic impacts of refugee crime on the offender's family and the offender post sentence and investigating what can be done to minimise negative impacts
Theme 1 **Understanding of the impact of police discretion whether to uphold or to apply the law in incidence involving refugees**	
Importance to New Zealand	It is important for New Zealand as it will highlight: refugees' experience towards the police, the impact of the option taken by the police, the existence of categorisation of refugees, the true figure of refugees who entered into contact with the criminal justice system. Whether the information held by the police, once shared, impacts on the views towards refugees and impacts their productivity.
Research components	Whether there is a mechanism for ensuring police comply or whether they are effectively able to choose. Whether the discretion exercised by Police is framed by the institution. Whether the discretion exercised may lead to no arrest even if there are enough grounds to do so.
Theme 2 **Understanding the experience of refugees in courts**	
Importance to New Zealand	Better understanding if refugees are likely to plead guilty or not guilty and why they do that. This helps to save time and money. It is understood that suspects who go through all steps until sentence increase the chance to get less punishment therefore getting employment very quickly. The productivity will increase.
Research components	Whether a refugee suspect is likely to be advised to plead guilty. Whether financial considerations influence the result of refugees in the court. Whether Lawyers and Judges share the same perceptions towards refugees.
Theme 3 **Understanding of the length of sentence afforded to refugees**	
Importance to New Zealand	This will help to identify shared aggravating and attenuant factors to the length of sentence afforded to refugees. If these factors have a big negative influence a policy should be developed to address the issue. This will help to get a lenient sentence which leads to minimum sentence.
Research components	Understanding the most crimes committed by refugees. Understanding of aggravating and attenuant factors.
Theme 4 **Understanding to the services afforded to the family of the offender**	
Importance to New Zealand	Understanding of the economical impact towards the family of the criminal. Understanding of what the government can do to help them to remain productive. What helps is it available after release?

Research components	The impact on family members of the offender. What are services for a released offender? Employers' perception towards offenders.
Research Gaps and Opportunities	Understanding the impact of the penal history of the vision of New Zealand as a "perfect society". New Zealand is known to have a high number of imprisonments. This is believed to have contributed by it is intolerance of crime. This will help to understand the psychological perception of members of the society towards refugees. Therefore may highlight where the government may emphasise in public education to understand refugees. Understanding the perception of refugees towards the criminal justice system. This will highlight how if a refugee has been in contact with the criminal justice system leads to personal limitation in exploring employment opportunity. Statistical Records do not facilitate researchers to undertake analysis of the data. The term "other" is a major obstacle as it is used to generalise all those who do not fall in the main categories. A clear record may help the analysis and may lead to attention of this data.
Comments	New Zealand has established a Quota Refugee System. These former refugees have managed to establish their communities. If you ask in public members of these communities if there is any one among them who is experiencing contact with the criminal justice system the answer is "my community is perfect". It seems to be a taboo to talk about their community. Which highlight the need to know what is happening the closed doors.
Grouping	Crime

Entry ID	**423**
New science, frameworks, approaches and tools are needed to ensure a sustained reduction in crime in the community and at the border. Our vision is of a New Zealand that is a safe place for all to live and prosper free from the social and economic costs of crime	
Summary	This challenge aims to ensure a sustained reduction in crime in the community. Scientific research to form the basis of these frameworks is needed across a range of disciplines (including biology, forensics, stats, social science, criminology) A further aspect of this research involves scientific solutions to border security.
Theme 1 **Innovative and transformative research and new technologies will ensure New Zealanders are safe in their homes and communities. Scientific advancements will be made in the prevention, detection, recording and solution of crime which will lead to sustainably reduced crime rates**	
Importance to New Zealand	Crime reduction is a key government priority as outlined in the Better Public Services Reducing Crime and Re-Offending Action Plan (July 2012) http://www.mbie.govt.nz/pdf-library/what-we-do/better-public-services/Better-

	public-services-action-plan-aug-2012 and improvements in the detection, recording and solution of crime are key components of the criminal justice pipeline. This is reinforced by the Directions in Australia New Zealand Policing 2012-2015 report (Standing Council on Police and Emergency Management) http://www.anzpaa.org.au/corporate-news-and-publications/news/7137, whose vision is Safe and Secure Communities in Australia and New Zealand and in the New Zealand Police Operating Strategy 2011-2015, Prevention First, http://www.police.govt.nz/about/strategy. A multidisciplinary approach including biology, molecular biology, forensic science, chemistry, physics, engineering, statistics, bio-informatics, social science, criminology, computer science and crime science is required. Interacting with front line criminal justice practitioners, such as Police and the Judiciary, places the forensic scientist at the heart of the judicial process and makes science pivotal in the crime scene to court room continuum with a direct and visible impact on the public. Key government targets including reducing the rate of violent crime by 20% by 2017. Carrying out innovative and underpinning research and development in science and new technologies in support of the detection, recording and solution of crime will support these targets. Science activity in this area will also play a key part in addressing significant concerns of the New Zealand public such as the unacceptable rate of child abuse and the impacts of crime on society. These reductions will preserve and enhance community safety and security and contribute to resilient, sustainable and just communities.
Research components	1. Developing improved capability to detect, analyse, interpret and store images of physical locations and evidentiary items, using innovative digital media approaches to capture complex and dynamic situations enabling a better understanding and interpretation of such events that can be communicated more effectively to other participants in the criminal justice process including juries. 2. Innovative and novel methods for the identification and analysis of materials associated with crime requiring advances in the fields of genomics, proteomics and transcriptomics and incorporating cutting edge technologies such as next generation sequencing. 3. Inventive analytical tools to predict, identify and quantify newly discovered drugs of abuse using genomics and pharmacology to develop an understanding of effects of drugs and alcohol on the individual. This will generate new knowledge about how an individual's genetic make-up may influence their individual responses which may in turn lead to behavioural changes or death. This will complement our understanding of the social and economic cost of drug and alcohol addiction. 4. Develop a better understanding of the changes in the human body after injury and post-mortem, essential for the determination the sequence of events and cause of death which extends beyond the criminal justice system. 5. Carry out fundamental, underpinning research in support of enhanced scientific evidence interpretation where New Zealand can draw on extensive and well proven existing capability

Theme 2 **Understanding and communicating new knowledge derived from the analysis of information to others so that justice outcomes are understood and improved for all**	
Importance to New Zealand	When decisions are made that impact on the safety and security of individuals and their communities it is important that these are based on the best available data so that the best possible outcome is achieved. Decision makers include those responsible for government policy on where best to invest limited resources so that crime can be reduced or prevented. Other decision may be that of a jury member, entrusted with deciding about the guilt or innocence of an individual or a member of the public concerned about the crime occurring in their local neighbourhood. By carrying out appropriate, ethically sensitive research on properly collected, collated and maintained data and communicating the results of this research in an understandable, meaningful way, the public's trust in the law and integrity of the justice system will be supported and increased. Such communication requires in-depth understanding of the needs and context of the decision-maker as well as the methods, utility and limitations of the data collection and analysis. Vulnerable citizens are often caught in situations where crime and family violence are common place. Developing smart, innovative scientific solutions to identify these citizens is essential if New Zealand is to become a safe, secure place for families. An added benefit of research, decision making and communication of this type is a clear description of the value of science to the development and long term sustainability of safe communities. The enhancing the understanding of the benefits of science and technology amongst New Zealanders, is then enhanced, encouraging them to consider science and innovation as essential requirements for a 21st century New Zealand.
Research components	1. Understand how jury members, lawyers, the judiciary and members of the public understand and interpret forensic evidence and how this is used to inform the critical decisions that they make in the process of a criminal trial. 2. Research into the behaviours and motivations of offenders creating better predictive models of behaviour and identification of characteristics that may identify a perpetrator are required to identify recidivist offenders and provide effective intervention options. 3. Understand the impact of crime on the public including the changing demographic, the Māori world view of science, and the economic impacts of crime identifying issues and resources needed for effective solutions. 4. Improved intelligence and surveillance tools required to manage and visualise data, including evaluating, monitoring and predicting future drugs of abuse, international scams and frauds, electronic fraud, identity theft, analysis data from crime scenes and evidence, monitoring global crime trends and the management and security and transfer of digital information particularly remote services; using crime intelligence to inform strategies for disrupting and preventing crime. 5. Understanding the impact of the built environment on crime and crime prevention, developing innovative solutions to reduce or prevent crime through

	building design and town planning. Understanding the factors that reduce or interfere with the building of resilient communities, infrastructure and social cohesion. 6. Research to better understand the role of social media in criminal behaviour and developing effective interventions through ICT and communication tools. Research to understand the causes of cyber bullying and antisocial behaviour amongst children and evaluate effective solutions to reduce the impact of criminal behaviour on the young.
Theme 3 **The goal of this theme is create scientific solutions to maximise security at the border from a crime perspective. This includes identifying hazards entering and leaving the country and protecting New Zealand flora and fauna from illegal export**	
Importance to New Zealand	Despite the distance that separates New Zealand from its closest neighbours, New Zealand's borders are not completely secure. By developing and implementing effective and appropriate technologies, New Zealand's safety through border security can be enhanced. Infectious diseases and insect pests as well as animal and plant products are well recognised as posing a risk both to human health and to New Zealand's primary industries and research to identify and eradicate these agents is already carried out. The importation of drugs of abuse and precursor compounds to these drugs poses a risk to all New Zealanders, not only from the perspective of the effect on an individual's health and well-being but also to that of the community through well documented increased criminal activity associated with drug distribution, supply and use. Ensuring that the people who enter and leave New Zealand are legitimately entitled to do so requires consideration of privacy and individual rights, however, smart and innovative tools can be used and developed to assist in the rapid identification of people by biometrics at the border. In protecting the native flora and fauna of New Zealand and in contributing to the protection of equivalent protected species from elsewhere, New Zealand can play an important role in the conservation of species and the reduction of illegal trafficking. Minimising the risk to New Zealand of a CBRNE (Chemical, Biological, Radiological, Nuclear and Explosive) event by carrying out appropriate research will minimise the risk to New Zealand of such a catastrophic event.
Research components	Research components that address this theme include areas that are already part of the New Zealand research landscape. Science needs to address the following areas: 1. Tools and technologies for the sensitive detection, identification, control and eradication of hazards including infectious diseases and pests, "risky individuals", illicit drug and drug precursors at and before the point of entry on land or by sea, including risk analysis and surveillance to predict future trends. 2. A biometric capability that safeguards the concerns of New Zealanders is

	required. This research should determine the public perceptions of this intrusive technology evaluate its effectiveness and consider the implications of sharing personal data across international boundaries. Research into the feasibility and public acceptance of the rapid identification of individuals and family relationships by genetic testing in the customs hall is required. 3. The identification of illegally trafficked animal and plant products in both directions across the New Zealand border is recognised as a significant concern. New tools for the rapid identification of flora and fauna as it enters and leaves New Zealand are required. This includes the generation of reference sequence data for some species and the development of tools and techniques for identification, paralleling those already in place for human DNA profiling. 4. Underpinning research and development of appropriate analysis tools to respond to a significant CBRNE (chemical, biological, radiological, nuclear and explosive) threat of a terrorist nature is required to ensure that New Zealand remain safe from such events.
Theme 4 **Addressing the complex problem of crime and harm from drug and alcohol abuse through integrating and applying "crime science" and "services science" as an innovative coupled science platform**	
Importance to New Zealand	Reducing crime by reducing alcohol and drug abuse is a priority for New Zealand http://www.mbie.govt.nz/pdf-library/what-we-do/better-public-services/Better-public-services-action-plan-aug-2012. Services are a recognised intervention because alcohol and drug treatment is both effective and cost-effective. It reduces substance use and improves health and well-being. For every dollar spent on alcohol and other drug treatment programmes, there is a $4–$7 reduction in the cost of associated alcohol and drug-related crimes. Crime science is a radical departure from the usual ways of thinking about and responding to the problem of crime. It is concerned with near causes of crime – why, where, when, by whom, and how of crime. Crime science is practical in its orientation and is multidisciplinary: Jill Dando Institute, UCL, UK http://www.ucl.ac.uk/dji Services are vital to New Zealand's national productivity, economic performance (71% of GDP) and social well-being (New Zealand Economic and Financial Overview 2012. Skills Challenge Report, Department of Labour 2011). However the necessary knowledge base, methodologies and methods to support service innovation are inadequate. Services innovation and particularly the role of science, technology, engineering and mathematics has been a notable 'blind spot' for science and innovation policymakers. Poor understanding of services innovation models and practices and relative lack of academic and case study material has resulted in significant knowledge gaps (The Royal Society UK, 2009 report "Hidden wealth: the contribution of science to service sector innovation, http://royalsociety.org/policy/publications/2009/hidden-wealth). Services science has emerged as a novel interdisciplinary approach in response to this knowledge gap.

Research components	1. Understanding the wider crime – drug and alcohol 'service system' that involves multiple organisations and roles that are important for innovative science-based services. E.g. the roles of judges, drug treatment services, policy and regulators, illicit trade, industry, consumers. 2. Trialling and contributing to emerging theories of services, models of services, and service innovation through case study analysis of current innovative service trials. E.g. drug courts 3. Understanding how inter and intra organisational processes, culture, and structures, management and leadership can be shaped and designed to support a high-value services, including both public (justice, social welfare, health) and private sector services. 4. Understanding and developing technologies that support and aid design of high-value science-based services, including measurement technologies, visualisation (including geospatial mapping), and ICT information management technologies.
Comments	Services delivered through complex systems Dramatic changes in the nature of services will require new scientific approaches to understand, develop and manage them. As changes in technology enable closer and deeper interaction with users and greater personalisation of services - not withstanding that they may be provided from anywhere in the world - people will become key components in the system. Combined with the increasing tendency for services to be inter-linked, their dynamic, constantly evolving nature, and their long and complex supply chains, the result is an inherently non-deterministic, complex system with 'emergent properties' that are not predictable by separate analyses of the individual components. A systems-based approach to understanding services One solution may lie in the wider adoption of systems-based approaches to understanding services. A more systematic approach to studying services should result in better design, management and understanding of services and, at the same time, provide a suitable context in which to integrate disciplines such as social sciences, management science, economics and STEM. The emerging Service Science, Manufacturing and Engineering (SSME) or 'Service Science' concept is also intended to join up a broad range of disciplines, but is specifically concerned with ensuring that graduates are better equipped for the workplace. Service Science may ultimately help the development of multi-disciplinary capabilities but in this regard SSME programmes seem to have been slow to emerge and only partially successful to date. [Rhind, D. Gann D et al (2009) Hidden wealth: the contribution of science to service sector innovation. RS Policy Document. London, The Royal Society.]

6 Equitable Outcomes

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

Table 6: Summary of proposed challenges and themes

Entry Id	Challenge	Themes
298	Better life opportunities for school leavers of Māori and Pasifika and lower socio economic background by breaking the cycle of under achievement and addressing the issues that affect their education and youth environment.	1. Increase the number of Māori, Pasifika and lower socio economic students achieving NCEA level 2 or equivalent to more than 85% and reduce the likelihood of inter-generational transfer of poverty 2. Improve school attendance to more than 95% for Māori, Pasifika and lower socio economic students for all years of schooling. 3. Build strong positive community social capital in communities of diverse groups. 4. Build resilience in children of Māori, Pasifika and lower socio economic families so that they achieve positive outcomes despite the presence of adversity
478	Mātauranga: Valuing and enhancing Māori and Pacific knowledge and assets	1. Drawing on existing depth of Māori knowledge (philosophy, worldview) of place, of environment, etc. 2. Optimizing relationships with people and environment in surrounding waters 3. Innovative management and governance of natural assets– kaitiakitanga
483	Building a High Equity Society - To achieve national prosperity, we will need to achieve a progressive, free, democratic and high equity society, recognising the special place of Māori while embracing the multicultural society we have become and our future generations.	1. Education: Eliminating discriminatory outcomes 2. Eliminating Income Disparity 3. Health and Wellbeing 4. Lived Environment, Housing

Entry ID	298
Better life opportunities for school leavers of Māori and Pasifika and lower socio economic background by breaking the cycle of under achievement and addressing the issues that affect their education and youth environment	
Summary	The goal is to improve life opportunities for Māori, Pasifika and lower socioeconomic children. Themes include developing strategies to increase the number of Māori, Pasifika and lower socio economic students achieving NCEA level 2 and reduce the intergenerational transfer of poverty, improve school attendance for Māori, Pasifika and lower socio economic students for all years of schooling, understanding how to build positive social networks in culturally diverse communities to improve education and life outcomes, developing strategies to help Māori, Pasifika and lower socio economic children address adversity and achieve positive outcomes despite its presence
Theme 1 **Increase the number of Māori, Pasifika and lower socio economic students achieving NCEA level 2 or equivalent to more than 85% and reduce the likelihood of inter-generational transfer of poverty**	
Importance to New Zealand	Socially and economically disadvantaged students perform worse at all levels and this transfer to their life opportunities. The 78,074 people receiving long term unemployment in 2012 typically have low education achievement. Only 50 % of Māori and 57% of Pasifika students achieve NCEA level 2 by age 18. Poor education is a key vehicle for passing the cycle of poverty from one generation to the next.
Research components	Key issues for research are to better understand and develop strategies to address • Barriers to academic success in Māori, Pasifika and lower socio economic students and development of strategies to address these barriers • Development of longitudinal monitoring of learning for each student as a tool to identify problems at an early stage as a basis for intervention • Positive engagement between schools, teachers, students, parents/whanau and communities to support student achievement • Improved transition from primary to secondary schools for Māori, Pasifika and lower socio economic students.
Theme 2 **Improve school attendance to more than 95% for Māori, Pasifika and lower socio economic students for all years of schooling**	
Importance to New Zealand	Attendance at school and educational achievement are closely linked. Disengagement from learning is associated with poor qualifications, low paid intermittent employment, offending, poor health and quality of life. In 2011 the national absence from school rate was 10.2%, 14 % in secondary schools. The Māori and Pasifika rate was double that of New Zealand European and Asian students.
Research components	Key research issues include • Better understanding what motivates and demotivates Māori, Pasifika and lower

	socio economic students to attend school • What community characteristics support attendance and how can this be translated to communities that do not exhibit those characteristics • How to build effective collaboration between schools, iwi, and community stakeholders to promote positive engagement with education • Evidence based initiatives to support parents and teachers of children with behaviour issues
Theme 3 **Build strong positive community social capital in communities of diverse groups**	
Importance to New Zealand	Strong positive community social capital is closely linked to education achievement and pro-social behaviour. Communities significantly influence whether children are protected or exposed to harm. Poor education and life outcomes are associated with low levels of social integration. The 152,800 care and protection notifications of abuse in 2012 underlines the importance of this issue.
Research components	Key questions are • How to build density of positive social networks in culturally diverse communities. • Strategies to help families and communities cope with adversity and to develop a positive outlook • The potential role of schools in building strong positive community social capital • What factors will enable the resilient family of the future • Develop methodologies to measure and tune the impact of initiatives on communities.
Theme 4 **Build resilience in children of Māori, Pasifika and lower socio economic families so that they achieve positive outcomes despite the presence of adversity**	
Importance to New Zealand	270,000 children live in poverty and are at risk of poor life outcomes. It is important to develop the means to build children's resilience to achieve positive outcomes despite adversity. Childhood adversity and trauma affects sociability, motivation, self-regulation, attention, and self-esteem.
Research components	Issues for research include • Research and development of strategies to help Māori, Pasifika and lower socio economic children address adversity including o Interventions and pedagogy to support cognitive development in early childhood education and primary school o Community interventions to build self-belief and esteem and a sense of identity • Better understanding the drivers and triggers of depression in children • Use data mining techniques to identify and monitor children, families and communities at risk.

Research Gaps and Opportunities	Key gaps are 1. Understanding the barriers to academic success for Māori, Pasifika and lower socio economic children as a foundation for changing teaching practises and community engagement in education 2. Understanding the motivators and success factors for social networks in culturally diverse communities in order to provide better foundations for interventions aimed at building positive community social capital 3. Methods to use existing data such as data mining to measure and monitor all aspects of a child's progress in and out of school throughout schooling.

Entry ID	**478**
Mātauranga: Valuing and enhancing Māori and Pacific knowledge and assets	
Summary	This challenge proposes to increase the value and usefulness of Māori/Polynesian cultural knowledge. Research goals will draw on a depth of pre-existing knowledge (worldview, philosophy) to; develop measures that can be used to strengthen and monitor both individual and community resilience, optimise relationships and increase interactions between young people and their environment (particularly in terms of fisheries management and climate change) which will help retain young individuals within their communities, and develop innovative management and governance strategies of natural assets (with a focus on sustainable resource use).
Theme 1 **Drawing on existing depth of Māori knowledge (philosophy, worldview) of place, of environment, etc.**	
Importance to New Zealand	Develop measures to determine contribution of community resilience to individual resilience and monitor over time Develop measures to describe the differential exposure to costs of adaptation to environmental change by different communities and monitor over time
Research components	6.1.1 Identifying factors that focus on building the community as well as growing the individual in society 6.1.2 Understanding costs and benefits of human contributions to environmental change as seen by society e.g. differential susceptibility of Māori and Pacific communities to climate and sea level change
Theme 2 **Optimizing relationships with people and environment in surrounding waters**	
Importance to New Zealand	Proportion of young people remaining within their own communities and environments
Research components	6.2.1 Understanding optimal economic relationships with the fishery in sustainable ways using enhanced technology for surveillance and monitoring of harvest and or

	extraction of resources 6.2.2 Identifying approached for building mutually beneficial relationships across the Pacific region that reflect our people's interests and ensures a stable, peaceful and prosperous future through cooperation across social, economic, scientific and cultural activities 6.2.3 Understanding impacts of climate change and ocean acidification on coral reefs as key components of tropical ecosystems and the populations they support
Theme 3 **Innovative management and governance of natural assets– kaitiakitanga**	
Importance to New Zealand	Establish measures of sustainable resource use that can compare long term differences in performance of assets (both economically and environmentally) owned communally by Māori with those in private ownership
Research components	6.3.1 Developing sustainable and affordable energy technologies based on communal ownership of energy resources 6.3.2 Understanding unique opportunities for long term management of land and water based assets that are held by Māori communities
Research Gaps and Opportunities	The intellectual traditions, assets and young populations of the Māori and Pacific communities represent a significant opportunity for the nation. They provide contrasts in philosophy, history and concepts of ownership that expand our ability to understand the world and New Zealand's place within it. Indigenous people explicitly place themselves within their environment and challenge views that separate people from the environment. The expanded national vision that arises from this indigenous tradition can greatly diversify the opportunities for New Zealand's social and economic development.

Entry ID	**483**
Building a High Equity Society - To achieve national prosperity, we will need to achieve a progressive, free, democratic and high equity society, recognising the special place of Māori while embracing the multicultural society we have become and our future generations	
Summary	This challenge proposes developing educational models to eliminate discriminatory outcomes, eliminate income disparity through outreach programmes, and identify and prevent factors which lead to disparities in health outcomes.
Theme 1 **Education: Eliminating discriminatory outcomes** **Potential measures: Achieving parity in educational outcomes across all educational sectors by 2050 (or similar)**	
Research components	0.1.1 Identifying innovative education models that grow the entrepreneurial, management, social, cultural, scientific, environmental and economic development capability of all communities

	0.1.2 Understanding how to better educate and train people to work in their communities – what do communities need? How do educational institutions calibrate/respond to communities' needs? 0.1.3 Identifying and evaluating educational outcomes from Teenage Pregnancy Units and develop transitional strategies to guide young women into further education and long-term employment
Theme 2 **Eliminating Income Disparity** **Potential measures: Bring low income population groups' income levels to a par with the general population by 2050 (or similar)**	
Research components	0.2.1 Developing innovative mission-critical time-bound training and development programmes for different low income population groups 0.2.2 Understanding how to improve financial literacy outreach into low income communities 0.2.3 Developing innovative high-impact models that increase workforce skills; that take into account the different changing demographics of different groups (recognising that even in an ageing population the Māori and Pacific age profile is younger, for example). 0.2.4 Increasing understanding of culturally specific ideas about rewards, incentives, and promotional opportunities 0.2.5 Investigating effective, family-friendly work-place models and flexible working arrangements 0.2.6 Developing appropriate measures and indicators that include Māori and Pacific concepts of poverty and wealth, to allow for a more mindful understanding of how Māori whānau and Pacific families and children experience poverty and the production of Māori/ Pacific-centred data. Data on Māori and Pacific whānau also needs be better disaggregated to allow for a more nuanced understanding of the diversity of experiences of whānau.
Theme 3 **Health and Wellbeing** **Potential measures: Achieve parity for Māori and Pacific peoples with non- Māori and non-Pacific population in health outcomes by 2050 (or similar) Eliminate the ten year disparity in life expectancy between Māori (and other demographic groups with significantly lower than average life expectancy) and the general population by 2030 (or similar)**	
Research components	0.3.1 Identifying the root causes for disparities in health outcomes for Māori and Pacific peoples and develop interventions to resolve them 0.3.2 Developing strategies and initiatives that address issues relating to Māori and Pacific suicide and self-harm 0.3.3 Developing a Māori and Pacific food nutrition strategy

Theme 4 Lived Environment, Housing Potential measures: Decrease overcrowding for Pacific and Māori families by 75% by 2025 (or similar) Increase the provision of social, community and iwi housing by 40% by 2025 (or similar) Extend insulation programmes to the remaining estimated 700,000 homes that need it by 2017	
Research components	0.4.1 Responding to the serious undersupply of housing by developing environmentally sound materials (e.g. whare uku) for Māori and Pacific social/iwi housing 0.4.2 Developing a framework for culturally appropriate housing models to meet the needs of Māori and Pacific Island communities/whanau

7 Resilience to Hazards

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

Table 7: Summary of proposed challenges and themes

Entry Id	Challenge	Themes
90	Understanding the likely impacts of anticipated changes in land cover and usage, and in climate change, on wildfire threat will be a key considerations for any approach to forest and rural fire management in the regions as the environment becomes more changeable	1. Enhanced risk assessment tools for the rural fire hazardscape 2. Building community resilience 3. Fire's role in the New Zealand landscape 4. Improving safety and capacity in the rural fire workforce
172	By accelerating the understanding of natural hazard processes, their impacts and mitigation options, coordinated through the Natural Hazards Research Platform, New Zealand will have more social and economic resilience, and will become a world leader in national risk management	1. Developing quantitative frequency-magnitude and forecast models of geological and weather-related natural hazard events in New Zealand 2. Determining building and infrastructure performance that provides resilience to natural hazard events at socially acceptable levels of risk 3. Understanding the social factors determining resilience to natural hazards in family, community and business 4. Socio-economic risk models of natural hazard impacts to underpin effective national risk management
193	To make our economy, infrastructure and society as resilient as they can be to the effects of natural disasters. Resilience infers an ability to survive a crisis and thrive in a world of uncertainty.	1. Better management of natural hazard risks through the application of improved knowledge of their likely frequency, nature and characteristics to better understand our vulnerability and what can be done to reduce it. 2. Safer communities and better-informed land use planning and development through improved application of the knowledge of the susceptibility of land and structures, and of effective mitigation measures. 3. Less damage to buildings after a disaster, a more consistent national approach by the establishment of performance expectations for structural and non-structural elements and preservation and greater safety of existing townscapes and heritage buildings. 4. Communities supported to become resilient to disasters through better-targeted and more effective measures to minimise the social and

		economic disruption to people's lives.
243	Adequately find the characteristics of active and inactive faults especially in or near major urban areas	1. Do land surveying, monitoring of mass land movements, and seismic work to adequate depths
253	Highly detailed, high quality mapping of New Zealand's terrain using LIDAR for infrastructure and hazard planning	Providing a comprehensive set of terrain height data over all of New Zealand for development, infrastructure and hazard planning.
269	Resilient and safe communities even in the face of natural disaster. This is to be achieved through making our energy supply and information technologies resilient to loss or damage.	1. To make our electricity and distribution network more resilient to natural hazard and possible cyber attack. 2. To make our electricity and distribution network more resilient to natural hazard and possible cyber attack. 3. The goal of this theme is to develop and apply methods that will; make our society more robust to disaster events, to speed the social and economic recover from such events and to stimulate elements of the economy through building ICT skills.
291	Understand the likely impacts of changes in social, environmental and economic outcomes in regard to wildfire threat in New Zealand.	1. Minimising the risk 2. Build community resilience 3. Increase understanding of the role of fire in the New Zealand landscape 4. Improving the safety and capacity in the rural fire workforce
357	New Zealand is vulnerable to a range of geo and climatic hazards and the goal of the Challenge is to improve New Zealand's resilience to these types of hazards.	1. The goal is to improve damage resistant technologies to strengthen existing earthquake prone buildings and new buildings to meet post event serviceability requirements. 2. The goal is to improve techniques for retrofitting earthquake resistant techniques to underground infrastructure. 3. The goal is to improve responses and recovery to future major catastrophic events of the scale of the Canterbury earthquakes. 4. The goal is to raise the quality of engineering interventions to reduce risk from natural inundation hazards, whether these originate from tsunami, storm surge, tidal action, urban drainage failure, river flood or intense precipitation.
400	Big data strategies for tackling 'wicked' problems. - Climate change, sustainability and the effectiveness of emergency response systems are all part of	1. Interoperability. 2. Evolutionary Multi-objective Optimisation (EMO) and Multi-Criteria Decision Making (MCDM) 3. Visualisation

	the 'wicked' problems facing both our farms and cities in the 21st Century. Big data should now be used by the science community to solve these.	4. Multi-Agent Systems
433	Resilience to hazards / coping with natural disasters	5. Technological infrastructure as an economic weak-point
445	Communities resilient to biotic and abiotic hazards	1. Readiness – forecasting hazards 2. Reduction of the impact of hazards (including mitigation) 3. Resilience 4. Value creation
463	Increased Resilience to Natural Hazards. Goal: To increase New Zealand's economic and social resilience to natural hazards, by quantifying the risk to production, infrastructure and community activities, based on accelerating the understanding of hazard processes, impacts and mitigation options.	1. Developing quantitative frequency-magnitude and forecast models of natural hazard events. 2. Determining building and infrastructure performance that provides resilience at acceptable levels of risk. 3. Social factors that determine resilience. 4. Risk models of natural hazard impacts.
466	Safe, Healthy and Resilient Communities	
482	Infrastructure, hazards and us	1. How do we understand current and future infrastructure needs and resources? 2. Evidence-based decision making for economic management of infrastructure 3. Developing and managing the opportunities, and economic and social trade-offs 4. Understanding New Zealand's current and future hazards, their risks and impacts
485	Fire, a natural hazard: resilience and prosperity.	1. Advance devastating force risk assessment systems through improved understanding of destructive hazards. Integrate wildfire risk with other hazard assessment tools and through science, expand our knowledge of the impacts of fire on NZ's productive and natural ecosystems 2. Develop science to enhance community resilience and adaptive capacity to rural fire 3. Accessing the benefits of hazards - enhance the use of fire as a viable tool for agriculture, forestry and pest management 4. Technology for hazard benefits and hazard devastation 5. Impact of future changes on hazard management and preparation

Entry ID	90
Understanding the likely impacts of anticipated changes in land cover and usage, and in climate change, on wildfire threat will be a key considerations for any approach to forest and rural fire management in the regions	
Summary	Risk assessment tools need to be developed that integrate climate change, land use, and demographic structure to reduce the current and future effects of wildfires/ rural fire. This will involve better preparing communities to face wild fires, and developing strategies that ensure communities are adequately prepared to respond to any wild fire threats. The use of fire as a land management tool should also be studied to ascertain and reduce any ecological or climactic effects.
Theme 1 **Enhanced risk assessment tools for the rural fire hazardscape**	
Importance to New Zealand	Risk assessment tools need to be refined to reflect emerging risks associated with climate, land use and demographic change, and to ensure that the latest technology and knowledge are incorporated into risk assessment tools to ensure threats from rural fire now and in the future are reduced.
Research components	• Develop measures to ensure that a national fire danger rating system reflects the current and changing fire hazardscape? • Identify how fire danger rating knowledge is incorporated into tools that inform fire management strategies?
Theme 2 **Building community resilience**	
Importance to New Zealand	The majority of New Zealand communities have a low awareness of the risk of forest and rural fire and do not have a high level of preparedness for facing forest and rural fire events.
Research components	• Develop tools to identify what is the perception of the risk of rural fire in New Zealand communities and community expectations for fire risk mitigation and response. • Identify the key rural fire messages which need to be developed for communities and how should they be delivered. • Identify the best strategies to develop effective community readiness to protect at-risk communities.
Theme 3 **Fire's role in the New Zealand landscape**	
Importance to New Zealand	Fire is currently used as a land management tool across New Zealand. However, guidance around the use of fire in the landscape is needed to maximise economic benefit, protect New Zealand's vulnerable ecosystems, and maintain biodiversity to lead to more sustainable land use. As over 99% of rural fires are caused by human activities, this theme represents a core area where the number of fire incidents can be reduced and conservation values protected.
Research components	• Develop tools to reduce the risk and impact of fire under changing land use and climate. • Identify the current issues for people wanting to use fire as a land management tool. • Identify what research is needed to enable the safe and effective use of fire as a land management tool.

	• Identify what research is needed to understand the full effect of fire on land and ecosystems.
Theme 4 **Improving safety and capacity in the rural fire workforce**	
Importance to New Zealand	The changing demographics within rural communities mean that it is getting harder to attract and retain volunteers and paid staff in the rural fire workforce. The continued loss of experienced staff from fire organisations and the lack of prescribed burning make it difficult for new members to gain practical knowledge and experience. Safety of firefighters and communities is of paramount importance. The sector needs to develop a stronger organisational safety culture, whereby lessons are learned from major incidents and best practice guidelines on safe and effective fire suppression are developed and implemented nationally.
Research components	• Develop tools for the recruitment, retention and succession of firefighters and managers. • Develop tools to provide a national organisational safety culture where lessons from near-misses, accidents and serious harm incidents are adopted across the sector. • Develop best practice guidelines for safe and effective fire suppression to minimise risk.
Research Gaps and Opportunities	1. Increased understanding of the rural forest and fire hazardscape and therefore to more effective fire risk management. 2. Enhanced community awareness and understanding of the risk of rural fire, greater understanding of fire agencies of their communities and an increase in the level of preparedness and resilience of at-risk communities. 3. Clear guidance on the sustainable use of fire as a land management tool to maximise the economic return from land while protecting important biodiversity values and vulnerable ecosystems from both wildfires and fire use impacts. 4. Safer and more productive firefighters, and to more professional and knowledgeable fire managers, thereby resulting in safer, more efficient and cost-effective fire suppression. 5. Underpin effective investment and allocation of scarce resources towards those strategies and activities that yield the greatest benefits. Importantly, these decisions will consider the full range of values and assets that benefit most from rural fire mitigation measures.

Entry ID	**172**
By accelerating the understanding of natural hazard processes, their impacts and mitigation options, coordinated through the Natural Hazards Research Platform, New Zealand will have more social and economic resilience, and will become a world leader in national risk management	
Summary	The goal is to create resilience to natural hazards in both buildings and communities. Themes include understanding individual hazard processes (location, frequency, magnitude etc.) and developing models of hazards and associated effects, application of sound engineering principles to address building/infrastructure collapse and damage control and understanding the social factors determining resilience in family, community and business and developing socio-economic risk models of natural hazard impacts

Theme 1 **Developing quantitative frequency-magnitude and forecast models of geological and weather-related natural hazard events in New Zealand – GNS Science, NIWA, University of Auckland, Massey University, University of Canterbury, Victoria University, Lincoln University**	
Importance to New Zealand	It is recognised that natural hazard events, such as the Canterbury earthquakes, pose the most likely, potentially catastrophic impacts on New Zealand, in terms of lives lost or damaged, infrastructure destroyed and social well-being diminished (http://www.dpmc.govt.nz/node/930, page 22). However, in order for New Zealand to mitigate these impacts (i.e. reduce the social and economic cost to the country) it is necessary to understand why volcanoes, earthquakes, landslides, tsunami, river floods, coastal erosion and storm surge, extreme wind, snow, and hail, occur where they do, at what frequency, in what magnitude range, and how they intersect with urban areas and the rural economy. From the fundamental understanding of individual hazard processes, we can make quantitative estimates of each hazard and associated cascade effects (a "multi-hazards" approach) using probabilistic modelling methods for individual, and integrated, perils. These models provide the hazard component of the risk equation. A key element to reduce impacts is the ability to forecast hazard events when these are likely to exceed current mitigation. This is particularly applicable to weather, flood and coastal storm surge hazards, where more accurate warnings will model, in real time, the impacts of forecast events, and guide emergency response. With improved understanding of the driving forces of natural processes then time varying forecasts of when these natural hazard perils may strike is becoming a reality. Forecasting weather-related hazards is further advanced than for many of the geological processes although good progress is being made in forecasting earthquake aftershocks and volcanic eruptions.
Research components	Key research questions for natural hazards quantification in New Zealand include: • What is the average and maximum size, and timescale typical of different types of volcanism? What monitoring tools are most useful at different types of volcanoes, and how can modelling of magma genesis and volcano plumbing systems inform forecasting? • Can we determine the thresholds for landsliding related to earthquake and rainfall triggers, and what controls the variation in occurrence and size of landslides through time? • Do undersea landslides and volcanoes contribute significantly to tsunami hazard? Are debris and pollutants caught up in tsunami inundation an under-appreciated component of tsunami hazard? How effective are typical natural coastal landscapes at buffering tsunami attack? • Can we combine past and current records and effects of earthquakes (instrumental catalogue, historical accounts, active faults studies, GPS), to more accurately forecast future events? Can Canterbury and other data inform the relative importance of earthquake source characteristics, the travel path effects,

	and the influence of near-surface soil properties, on earthquake damage? • What are the key processes driving weather-related hazards (storms, floods, coastal, maritime, drought, snow/avalanche/hail, landslides (hydrological trigger), what are the full range of magnitude and frequency characteristics in different areas, and how can we develop improved predictive models? How can we improve flood forecast accuracy and forecasts of inundation depth in advance of and during flood events? • How can we better simulate storm surge and coastal erosion/accretion in the near-shore and foreshore, and the evolution of coastal margins?
Theme 2 **Determining building and infrastructure performance that provides resilience to natural hazard events at socially acceptable levels of risk – University of Auckland, University of Canterbury, GNS Science, Opus International, BRANZ**	
Importance to New Zealand	Enhancing the resilience of our communities to the effects of natural hazard events, and thus reducing the social and economic cost, involves application of sound engineering principles to address both building collapse and damage control and the preservation of key lifelines in order for them to remain operational. Engineering research will provide a performance-based framework within which both life safety and operational functionality are achieved in a cost-effective manner. When implemented, community impacts experienced during an event will remain within tolerable limits and people will, in the main, be able to continue living within their homes. Critical services, although they can be expected to be disrupted, will be restored, within acceptable timeframes to avoid lengthy societal disruption with consequent economic impact. A performance-based framework will be used to design for damage control to both new buildings (and infrastructure) and to establish mitigation and strengthening (retrofit) provisions for our existing built environment, including buildings, bridges, dams, water supply and waste networks, and energy and communication networks.
Research components	Key research questions for resilient engineering and infrastructure research include: • How can we develop a suitable, probabilistic, performance-based engineering framework that will ensure existing and future buildings and infrastructure meet target performance levels so as to enable rapid and cost-effective restoration of fully functioning communities following a natural hazard event? • How can we determine how buildings be economically designed, built and/or retrofitted so as to match the societal performance expectations, both during and following, a natural hazard event? • How can we determine how critical infrastructure and lifelines systems be designed, built and/or upgraded so as to maintain their life support function following a natural hazard event, being cognisant of the high level of interdependency between such networks?

	• How can alternate approaches to performance based design be used to evaluate the current building and infrastructure stock and retrofit options to determine effective risk treatment against expected future occurrence of earthquakes, tsunami, wind, flood, and volcanic ash?
Theme 3 **Understanding the social factors determining resilience to natural hazards in family, community and business - GNS Science, Massey University, Opus International, University of Canterbury, Lincoln University, Ngai Tahu**	
Importance to New Zealand	Developing a fuller understanding of the way individuals, communities, and organisations operate within complex natural and social systems is necessary in order to best prepare for and respond to the adverse impacts of future natural hazard events, such as downstream mental health issues and increases in domestic violence. Understanding how risks are interpreted and how these interpretations inform decision-making and actions is an important component in developing the knowledge base in this area, and underpins current research in societal resilience. Decision-making, particularly under conditions of uncertainty, can no longer be adequately accounted for using traditional models of 'rational choice'. Instead, attention needs to be paid to how risk interpretations are shaped by individual and collective experience, values, cultural beliefs and interpersonal and societal dynamics. Enabling, via evidence-based research, an understanding of the characteristics of a well-prepared, adaptive, and thereby resilient society or community represents the value that this research can bring to improved natural hazard resilience in New Zealand
Research components	Key research questions for understanding societal resilience • What societal factors and strategies enable strong communities that are resilient to the impacts of natural hazards? • What factors contribute to cascading failure across societal sectors, networks and groups and how can these be mitigated? • What is the vulnerability of the economy to natural hazards and how do factors such as the economic structure, stage of development, prevalent economic conditions and the policy environment play a role in that vulnerability? • What trends and emerging issues in our society influence vulnerability and resilience to natural hazards? • What evidence-based strategies for improving resilience are most likely to be adopted in governance, planning (including land use), and policy, organisational, economic and legislative frameworks? • What policy and procedure opportunities exist that will afford integral understanding, application, management and utilisation of disaster risk reduction science within planning, risk and adaptive management processes? • What improved communication methods and tools will facilitate the transfer of hazard and risk knowledge to stakeholders?

	• How effective are emergency management procedures and crisis management practices for optimising societal response to warnings and hazard events? • What are the steps by which society transitions, recovers and adapts (and how can these be enhanced) after the disruption caused by natural hazard events?
Theme 4 **Socio-economic risk models of natural hazard impacts to underpin effective national risk management – GNS Science, NIWA, University of Canterbury, Massey University, MOTU**	
Importance to New Zealand	The physical, social and economic impacts of natural hazard events or processes on societal function in New Zealand are acceptable only when they remain within tolerable limits. Thus, important products of risk modelling research are suites of alternate scenarios informing, in a socio-economic context, definitions of acceptable and tolerable. No such basis for risk management in New Zealand is currently available. Aspects of impacts that must be included in modelling include physical damage, direct and in-direct losses, casualties, transport, business and social disruption, and loss of agricultural production. Comparing risk posed by different natural hazards in a consistent way that incorporates a range of potential impacts and consequences provides the essential quantitative basis for mitigation options and response actions to improve resilience. A nationally consistent dataset of exposure and related vulnerability of the built environment and social characteristics of communities, coupled with probabilistic basis hazard simulations that include cascading hazard impacts and inter-dependencies, enables proper comparison between equally likely hazard events. Using an enhanced RiskScape tool (see new opportunity) quantitative models can inform options to: a) help to prioritise investments in specific measures that reduce the risk (e.g., earthquake strengthening of buildings, upgrading stop-banks); b) identify appropriate land-development planning that is truly cognisant of the level of natural hazard risk; c) deliver natural hazard risk models to the insurance industry to reduce premium for uncertainty and provide an improved technical basis for underwriting, and; d) prepare effective emergency management response plans and regular exercising using realistic risk scenarios.
Research components	Key questions for quantifying natural hazard risk • Which natural hazards pose the greatest risk to our communities i) on an annual basis, ii) on a moderately long term basis (5-10% probability over 50 years)? What gaps need to be addressed in the hazards themes to enable their intensity to be modelled for single sites, cities, or nationally? • How can we include consequential hazard effects (e.g. fire following earthquake, debris laden flood flows, earthquake induced ground deformation, climate change driving changed weather hazards) in probabilistic impact models?

	• How best to incorporate the cost of social and economic disruption into loss models? • How can supply chain disruption be incorporated into impact models? • How can we modify our exiting community models to reflect the society of tomorrow (e.g. allowances for green-field growth, urban densification, new building technologies and changing societal expectations)? • Can we model the impact of future events by consideration and adjustment of past ones (i.e. what is needed to incorporate variations in time and space?)? • How can indirect consequences of hazard events be anticipated and included within loss models? • How can uncertainty in loss models be quantified and expressed most robustly, and represented in alternate mitigation options (perhaps incorporating weighted decision tree options)? • What are the most appropriate formats for natural hazard risk impact models so as to ensure most effective utilisation by research users?
Research Gaps and Opportunities	Applying natural hazard research to demonstrate and promote National Risk Management action – all Platform partners and contractors will be involved The Canterbury earthquakes have exposed the need for all aspects of risk management to be better integrated. Recent engagement with re-insurers, who together cover two-thirds of the insured losses in Canterbury, has revealed a thirst to obtain the best local source hazard and risk information across all stages of risk management: identification, assessment, mitigation, adaptation. Giving industry confidence in our approach to national natural hazard risk management is critical for New Zealand's economic resilience. We propose to (1) accelerate development of the Riskscape modelling tool, to complete its application across all stages of risk management, and (2) form a small focused team to meet New Zealand's risk management knowledge transfer needs internally and externally. Interested parties include: • Central and regional government agencies, including MBIE, Treasury, MCDEM, EQC, and NZ Transport Authority • Insurers, reinsurers, and their technical advisors • Business, including banking, construction, and finance New Zealand can become a world leader in National Risk Management. Modest investment ($4 million pa) for improved and communicated hazard risk impact models has the immediate potential in just the insurance sector of significantly reducing New Zealand's c. $400 million annual reinsurance spend on earthquake cover, and reducing the likes of the $30 billion insured losses resulting from the Canterbury earthquake sequence. Fuller resilience benefits across all aspects of New Zealand society and economy will flow.

Comments	Recognition that natural hazard risk management is a national science challenge began with formation of the Natural Hazards Research Platform in 2009. There was widespread recognition of the need for long term stable funding for basic and applied science to bring about improved resilience to natural hazards, as well as recognition of existing good stakeholder engagement with the research. The Platform comprises six partner agencies (GNS, NIWA, Auckland, Massey and Canterbury universities, and Opus International). Twenty further agencies are subcontracted for work in the Platform and, in total approximately 165 researchers and >60 postgraduate students are supported by Platform funding. The science challenge presented here arises after reflecting on the history of New Zealand hazard events alongside lessons learned from the Canterbury earthquake sequence. This reveals gaps in our understanding of vulnerability and in the products we use to communicate with stakeholders. We now realise there are significant stakeholders outside of New Zealand, particularly in the insurance industry. In this submission for additional funding we highlight the immediate benefits to the insurance sector of further support for the Natural Hazards Research Platform national science challenge, but there are many wider benefits. These include: • Demonstrating the future natural hazard risk profile at the national scale and via realistic scenarios to business, the Crown, regional and local government, and the public. • Providing policy- and decision-makers with options for comprehensive natural hazards risk management. • Providing key government agencies with realistic future impact forecasts so that alternative risk transfer mechanisms can be explored.

Entry ID	**193**
To make our economy, infrastructure and society as resilient as they can be to the effects of natural disasters. Resilience infers an ability to survive a crisis and thrive in a world of uncertainty	
Summary	The goal is to create resilience to natural hazards in both buildings and communities. Themes include: combining knowledge of the probability and impact of hazards to develop computerised models of possible future experiences; enabling communities to make better informed decisions with the use of knowledge of the susceptibility of land and structures, and effective mitigation measures; reducing damage to buildings and infrastructure after a disaster through engineering research and new technologies; improving understanding of the social consequences of natural hazards to be able to minimise disruption to people's lives

Theme 1 **Better management of natural hazard risks through the application of improved knowledge of their likely frequency, nature and characteristics to better understand our vulnerability and what can be done to reduce it**	
Importance to New Zealand	We live on the boundary between two of the fastest-moving major tectonic plates in the midst of the roaring forties. As a consequence of this setting, our society is exposed to a wide range of geological and weather hazards ranging from frequent but modest events to rare but devastating disasters. So that steps taken to improve our resilience against these natural hazards are aimed at the most relevant outcomes, we must understand the probabilities and impacts of the natural hazards that occur in New Zealand. Probability (the likelihood of an event's occurring) is understood through research into the natural phenomena that can create the hazards – weather, flooding, seismic activity, volcanism and ocean behaviour – and the climatic, topographical and geological environments in which they happen. We have taken advantage of New Zealand's unusual status as a natural laboratory and created a strong research culture that has delivered benefits to our own society and the world. Continued leadership and collaboration will bring benefits not only to our own resilience but to our country's reputation and economy. The impact of a hazard is influenced by land use, the robustness of the structures we build and the effectiveness of mitigation measures. Combining our knowledge of the probability and impact of hazards to develop computerised models of possible future experience gives us a valuable tool that enables the measurement of risk to inform economic and planning decisions.
Research components	1. Assessment of the probability of occurrences of significant geological and meteorological events 2. Assessment of the impacts of such events on our communities and built environments 3. Development of hazard models such as RiskScape and maps to enable the practical application of the science 4. Development of reliable forecasting models for planning of activities and community development
Theme 2 **Safer communities and better-informed land use planning and development through improved application of the knowledge of the susceptibility of land and structures, and of effective mitigation measures**	
Importance to New Zealand	How people interpret and respond to risk is vital knowledge for any strategy for defining acceptable risk. Acceptable risk in the context of building safety involves interactions between physical and engineering factors on the one hand and human behavioural factors on the other. Decision-making under conditions of uncertainty is not adequately described by traditional models of rational choice. Personal experience, values and beliefs have to be mixed with societal dynamics to

	understand attitudes to risk. Lack of access to or framing of, risk information can contribute to misunderstanding of the extent of the risk. As we cannot eliminate risk altogether, a society's risk tolerance is a necessary starting point for any performance-based risk reduction regime. The science that will inform decisions should be encapsulated in user-oriented tools such as computer models and hazard maps. Users include individual property owners and other members of society who must make their own decisions based on their awareness and risk aversion. Our perceptions of risk are not logical but the result of our evolution as humans and biases as individuals. Communication of risk and desired reaction to it is a specialised area that is still being researched. The benefits of science input for evidence-based choices and decisions are more robust, better targeted outcomes for such activities as land use planning and better informed citizens when making their own choices about personal and family safety.
Research components	1. User-oriented tools to enable science input into decision-making activities, including the means to maintain the currency of these with the latest scientific discovery. 2. Support for evidence-based decision-making and communicating risk probability and impact, including the inevitable trade-offs among cost, convenience and prudence. 3. How people interpret risk and how best to communicate it to assist decision-making
Theme 3 **Less damage to buildings after a disaster, a more consistent national approach by the establishment of performance expectations for structural and non-structural elements and preservation and greater safety of existing townscapes and heritage buildings**	
Importance to New Zealand	Lessons from Canterbury and overseas earthquakes indicate that structural components of buildings have performed as expected, limiting or preventing building collapse. The challenge now is to reach the next level of performance, that of continued amenity, so that occupation and use of buildings remains uninterrupted after earthquakes. Non-structural components, e.g. cladding and glazing, have performed less well and buildings have become unusable either for living or business purposes. Aspects such as failure of storage systems in warehouses and supermarkets also fall into this category. The best long-term response is to establish performance standards for non-structural components that can be implemented cost-effectively for both new and retrofitted buildings. Another lesson from recent earthquakes is that buildings that withstand the earthquake attack themselves can still be adversely affected by the performance of adjacent structures and buildings in the vicinity. This can lead to widespread business interruption, as in the Christchurch CBD "Red Zone". Town and neighbourhood development may need to take a more holistic view of the risks involved than the current individual-structure based approach. There are significant benefits in comparing the efficacy of measures that have been taken to

	retrofit earthquake-prone buildings with levels of risk represented by other susceptible buildings. Near-design level earthquakes such as Darfield provide a uniquely comprehensive and relevant data-set. Benefits include more effective retrofit solutions including sensitive approaches to heritage buildings, the better identification of existing retrofits that are not cost-effective in mitigating risk and the improved categorisation of buildings that are potential candidates for retrofits.
Research components	1.Engineering research on effective retrofitting of buildings for natural disaster resilience 2. New technologies enabling innovative construction methods such as precast seismic structural systems and active link fractures in eccentrically braced steel frames 3. Improvements in design and fitting of non-structural building components such as cladding, glazing and industrial pallet racking systems 4. Understanding the performance of retrofitted and non-retrofitted buildings 5. Reassessment of building and infrastructure performance objectives and criteria
Theme 4 **Communities supported to become resilient to disasters through better-targeted and more effective measures to minimise the social and economic disruption to people's lives**	
Importance to New Zealand	A better understanding of the social consequences of natural hazard events will provide benefits to people and communities through improved mitigation and response measures. The indirect consequences include social dislocation, behavioural aspects for different age groups, family situations, genders and ethnicities, and knock-on economic effects from the disruption of businesses and services. An improved understanding of both short and long-term effects will come especially from investigating and assessing the disruption caused by actual events and the Canterbury experience will be invaluable in this regard.
Research components	1. Longitudinal studies of the impact and recovery in Christchurch, including economic impacts 2. Psycho-social recovery and community resilience in Canterbury in the face of living with severe disruption 3. Social research to support policy and operational activities that contribute to community resilience
Research Gaps and Opportunities	1. The experience of Canterbury and the extensive data available from GeoNet have created an unprecedented opportunity for evaluations of the impact of earthquakes on society, the built environment, housing and infrastructure. 2. Study of interlinking earthquakes and chains of disaster events 3. Studies and re-evaluation of previously underestimated types of event. 4. Mapping and evaluation of ocean-floor features in the EEZ 5. Development of the tools must be accompanied by guidance and training on

	how best to utilise them; the misinterpretation of hazard maps and models can be as damaging as not using them at all. 6. Decisions pertaining to hazard vulnerability are inevitably complex and at present there are no guidelines on how to negotiate the subtleties of context and acceptability. 7. The communication of scientific findings to those with responsibilities in public education is inadequate 8. The current bias towards earthquake resilience should be balanced by research into how volcanism, tsunamis, high winds, coastal erosion and slope instability could affect the built environment and infrastructure, in order for design and performance standards to take these into account. 9. Apart from the research into pallet racking systems there seems to be little investigation into how to make non-structural building components perform better. The sympathetic retrofitting of heritage buildings and upgrading of townscapes rather than individual buildings are also subjects for research investment. 10. There is an opportunity to investigate how closely the innate resilience of communities is linked to their normal development and the extent to which resilience can be designed into our community structures. Communities could be empowered to be more resilient by enhancing their existing capability and building partnerships between communities and hazard and risk experts.
Comments	This response had been prepared by members of the Strategic Advisory Group (SAG) to the Natural Hazards Research Platform. The SAG represents end-users of natural hazards research. Its members include representatives of government departments, lifeline utilities and local authorities. Since 2011, membership has been expanded to ensure the user needs for the Canterbury recovery are well represented. The SAG has also prepared a paper on the formation, administration and governance of the Natural Hazards Research Platform and is sending this to the co-ordinators of the national research challenges project for their information.

Entry ID	**243**
Adequately find the characteristics of active and inactive faults especially in or near major urban areas	
Summary	This challenge proposes a research programme to develop an picture of active and inactive faults to increase public knowledge of hazards and their location through land surveying, monitoring mass land movements and seismic work
Theme 1 **Do land surveying, monitoring of mass land movements and seismic work to adequate depths**	
Importance to New Zealand	To give a proper and adequate picture of active and inactive faults, so the population can be better informed of their characteristics-their location, when they last moved, their recurrence rate, their likely magnitude if they occur again. So

	the population can see where the hazards are on updated Hazard Plans, and are able to reduce their risk
Research components	1) and 2)The placement and monitoring of survey marks especially where there are known faults-active and inactive. 3)The seismic work to an adequate depth, at least to a 15km depth and if possible, especially in the zone of the continental and oceanic crust boundary

Entry ID	**253**
Highly detailed, high quality mapping of New Zealand's terrain using LIDAR for infrastructure and hazard planning	
Summary	This challenge proposes providing a comprehensive set of terrain height data over all of New Zealand for development, infrastructure and hazard planning e.g. data mapping of flood risk from rivers and coastal inundation
Theme 1 **Providing a comprehensive set of terrain height data over all of New Zealand for development, infrastructure and hazard planning**	
Importance to New Zealand	New Zealand has only a limited set of high-resolution terrain height information. This information is fundamental to many of our planning needs, particularly that around hazards and infrastructure development. LIDAR data is the primary source of this information, and can be collected efficiently and relatively cheaply over wide areas. While there is some LIDAR data for some areas, up till now this data has been collected on an ad hoc basis, with the data often only being made available for one of the many potential uses. There is a huge opportunity to collect this data for use by all New Zealanders and for many applications. No single user would collect such a set. There are many potential uses beyond infrastructure and hazard planning. Wikipedia lists 17 different categories of use covering many fields of science that are important to New Zealand (Agriculture, Archaeology, Biology and conservation, Geology and soil science, Meteorology and atmospheric environment, Law enforcement, Military, Physics and astronomy, Robotics, Spaceflight, Surveying, Transportation, Wind farm optimization, Solar Photovoltaic Deployment Optimization). One example of the use of this sort of data is the mapping of our flood risk from rivers and through coastal inundation. Currently available sets of data do not provide nation-wide coverage to sufficiently map our flood risks. LIDAR data could provide this fundamental data set.
Research components	This is a one-off proposal to collect a fundamental data set for use in many science applications. The research component would lie in the use by these other applications. with relevant industry then apply the new knowledge developed in (3
Research gaps and opportunities	This proposal offers to fill a large void in the quality and resolution of the terrain data New Zealand uses for its infrastructure and hazard planning. This is a missing fundamental data set for many areas of science.

Entry ID	269
Resilient and safe communities even in the face of natural disaster. This is to be achieved through making our energy supply and information technologies resilient to loss or damage	
Summary	The goal is to create resilience to natural disasters in communities. Themes include: making our electricity and distribution network more resilient to natural hazard and possible cyber attack, developing and applying methods of making our nation's information management and distribution systems resilient to loss, damage or destruction, investigating the way in which modern technologies can play their part in the social and economic recovery of society following natural hazard events
Theme 1 **To make our electricity and distribution network more resilient to natural hazard and possible cyber attack**	
Importance to New Zealand	This theme is important because the availability of power underpins practically every part of modern society including social and economic dependence. It represents part of the countries critical infrastructure.
Research components	•Research Component 1: Review methods for measuring network resilience in the electricity supply network including distribution automation. If methods of measurement do not currently exist or are inadequate then define new approaches for measuring resilience. This assessment should include both physical availability and vulnerability to cyber attack. •Research Component 2: Given an agreed approach to measuring resilience, quantify the current status of the nation's assets for energy generation, distribution and use. This to be undertaken on a regional basis. Such measurements can be used by policy makers to make strategic decisions on hardening the supply in certain areas. •Research Component 3: Seek new ways of energy generation, distribution and storage within the electricity supply network that are resilient to either natural hazard or cyber threat. This may include new network topologies that may span across distributed supply, monitoring, measurement, demand, control, use and even billing. It may also include localised sources of energy generation or storage. Such a problem will lend itself to network modelling. Control of the network may lend itself to analytics using the many real time or stored datasets representing the network health. •Research Component 4: In collaboration with relevant industry then apply the new knowledge developed in (3)
Theme 2 **The goal of this theme is to develop and apply methods of making our nations information management and distribution systems resilient to loss, damage or destruction**	
Importance	Historically, Information was recorded on paper and the ability to recall that

to New Zealand	information was a case collecting it from physical files. Security was a case of lock and key. Today, the amount of information stored has escalated by orders of magnitude and the ability to quickly recall and share it is essential in social, industrial and government contexts. Socially, the availability of records such as banking, retail and social media define our everyday lives. Economically the availability of records such as customer details, design information and plans are critical to our ability to do business. In a national context, access to large scale records such as population census and physical assets enable policy level decisions that affect everyone. Part of the research work is to measure the impact of information loss. Given that assessment one can assign metrics to the value of information and therefore the value of improving resilience. Given however that we all rely upon access to information, the value of making it more resilient seems self-evident.
Research components	Research Component 1: Review current methods of assessing resilience in the context of information management and distribution. If sufficient methods do not currently exist or are inadequate then define new methods. This measure of resilience should include the chance of loss, damage and cyber attack. The methods applied here should also include an assessment of the usability of this information given the application of proposed methods of resilience. Research Component 2: Given agreed methods of measuring resilience and usability in this context, undertake a review of the current state of New Zealand information systems (including physical assets, software assets and the communication paths between them). Information is a stimulator of the economy and as such we need to understand the relationship between resilience and the risk of throttling the usability of the information. Research Component 3: Given the assessment of (2), seek new ways of making information sources both resilient and usable. This may include new network topologies (national or local) that can be assessed through modelling. It also includes new methods of ensuring information security whilst balancing that with the need for the information to be sufficiently accessible to enable constructive social and economic use of the information. Research Component 4: In collaboration with relevant industry then apply the new knowledge developed in (3)
Theme 3 **The goal of this theme is to develop and apply methods that will; make our society more robust to disaster events, to speed the social and economic recover from such events and to stimulate elements of the economy through building ICT skills**	
Importance to New Zealand	Information and Communications Technologies are constantly changing the way we interact and do business. Recent events globally have illustrated the ever increasing dependence upon and social acceptance of ICT (mobile and fixed) in society. It affects both social behaviour and economic prosperity. This applies across our everyday lives and affects the way we respond to disaster events and the recovery thereof. This theme of work assesses the way in which modern technologies can play their part in the social and economic recovery of society

	following and event like Christchurch.
Research components	Research Component 1: Review current level of social dependence upon multi-media and mobile technologies. Use existing metrics where possible but new metrics may be needed. Include assessment of the way in which social media played a part in the events of the Christchurch disaster. Social media was used to both inform the public and manage situational awareness. Given this understanding new methods for social disaster management and relief can be derived. Research Component 2: Review the economic implications of information loss. This can be estimated through assessing the events of Christchurch. Given this understanding new methods for economic disaster management and relief can be derived. Research Component 3: Research how modern ICT systems can facilitate better management of disaster events. Assess the way in which such technologies can change inter-agency and also agency to public operations. Also explore ways in which socially relevant information could be made more resilient to loss through alternative forms of storage or redundancy. Research Component 4: Research how the Nation's economy can be made more resilient to disaster and ways in which our economy can grow through the availability of information anywhere anytime. After the Christchurch event, many workers were able to continue contributing to their companies though working remotely. The absence of the modern communication network may have made the effect on our economy substantially worse. Research Component 5: Engage with relevant agencies and industry to implement recommended methods and apparatus that build's the social and economic resilience of our country.
Comments	New Zealand exists in a world where social and economic prosperity depends upon key technologies; the supply of energy (electricity) and access to substantial sources of information through modern ICT networks. Society is symbiotically dependent upon the availability of these technologies and we must seek to make them resilient and secure. The goal of this research is to build resilience into these core technologies. In the absence of electricity, none of the modern computer, instrumentation or communication assets that society relies upon are available. In the absence of these assets information flow stops and with it the economy is vulnerable. The availability of information anywhere, any time is changing the social and economic dynamics of modern New Zealand. Everyday our information systems are exposed to the threat of cyber attack from those who would seek to steal, copy, expose, destroy or fraudulently use information of national, industrial or personal significance. The goal of this science challenge is to; a) build resilience into the core technologies that under pin our Nations society whilst simultaneously building the engineering capabilities within New Zealand

	resulting in skills to create new export value, b) evaluate the social and economic impacts of the loss or damage to these technologies. These innovations can be applied in the rebuild of Christchurch to form a modern Smart City. During the Christchurch event, many agencies and communities excelled in their response including supply of power and communications. This is laudable and we must learn from their efforts to apply that wisdom to our Nation's future cities.

Entry ID	**291**
Understand the likely impacts of changes in social, environmental and economic outcomes in regard to wildfire threat in New Zealand	
Summary	The goal is to improve knowledge of and resilience to rural fire threat in New Zealand. Themes include refining tools to minimise the emerging fire risks associated with climate, land use and demographic change, building community resilience to and awareness of forest and rural fires, increasing the understanding of the impacts of fire on New Zealand ecosystems and human causes of fire ignitions in New Zealand, improving safety, recruitment and retention of fire-fighters and rural land managers in the rural fire workforce
Theme1 **Minimising the risk**	
Importance to New Zealand	Tools need to be refined to manage the emerging risks associated with climate, land use and demographic change.
Research components	Specific research topics include: • Develop measures to ensure that a national fire danger rating system reflects the current and changing fire hazardscape? • Identify how fire danger rating knowledge is incorporated into tools that inform fire management strategies?
Theme 2 **Build community resilience**	
Importance to New Zealand	The majority of New Zealand communities have a low awareness of the risk of forest and rural fire. In many cases they do not have a high level of preparedness for facing forest and rural fire events.
Research components	Specific research topics include: • Develop tools to identify what is the perception of the risk of rural fire in New Zealand communities and community expectations for fire risk mitigation and response. • Identify the key rural fire messages which need to be developed for communities

	and how should they be delivered. • Identify the best strategies to develop effective community readiness to protect at-risk communities.
Theme 3 **Increase understanding of the role of fire in the New Zealand landscape**	
Importance to New Zealand	Fire is used as a land management tool in New Zealand. There is though a lack of understanding of the consequences of the impacts of fire on New Zealand ecosystems. Over 99% of rural fires are caused by human activities which is where the most effective research can be done to reduce the number of ignitions.
Research components	Specific research topics include: • Increase the research to understand the full effect of fire on ecosystems and processes. • Increase research to better understand individuals' activities that lead to fires ignitions in New Zealand.
Theme 4 **Improving the safety and capacity in the rural fire workforce**	
Importance to New Zealand	Safety of firefighters and communities is of paramount importance. There needs to be a stronger organisational safety culture. The decline in volunteers and paid fire management staff in the rural fire workforce is placing communities at risk.
Research components	Specific research topics include: • Research the most effective ways to recruit, retain and provide succession of firefighters and rural land managers with an interest in fire management. • Research the most effective tools to provide a national organisational safety culture. • Identify and develop best practice guidelines for safe and effective fire suppression to minimise risk.
Research Gaps and Opportunities	Optimise the management of fire on New Zealand's rural lands Sound, and appropriate metrics are required to understand rural fire management in New Zealand. The full benefits of the investments into different rural fire management strategies and tactics can be determined by the development of a comprehensive framework to quantify the total cost benefits that include direct, indirect and non-market values. Specific research topics include: •Investigate the most effective and appropriate tools to value the full cost of rural fire on social, environmental and economic resources. This includes direct, indirect and non-market values e.g. ecosystem services provided by indigenous ecosystems.
Comments	A great initiative.

Entry ID	357
New Zealand is vulnerable to a range of geo and climatic hazards and the goal of the Challenge is to improve New Zealand's resilience to these types of hazards	
Summary	The goal is to improve New Zealand's resilience to a range of geo and climatic hazards. Themes include improving damage resistant technologies to strengthen existing earthquake prone buildings and new buildings so that they are serviceable post earthquake, improving techniques for retrofitting earthquake resistant techniques to underground infrastructure, analysing the response and recovery from previous major catastrophic events to improve recovery and response in future, raising the quality of engineering interventions to reduce risk from natural inundation hazards and coastal erosion
Theme 1 **The goal is to improve damage resistant technologies to strengthen existing earthquake prone buildings and new buildings to meet post event serviceability requirements**	
Importance to New Zealand	New Zealand has a considerable legacy of unreinforced buildings and it is estimated that they comprise 8%-13% of the commercial building stock. In addition there is large number (unknown at this stage) of buildings that are less than 33% of the New Building Standard built up to the 1970s. The 1976 changes to design standards introduced requirements to design and detail building structures to protect vertical load carrying elements (generally columns). The intention was to avoid "pancaking" of buildings, even though this may mean subsequent demolition of the building. Post the Canterbury earthquake this approach is being questioned and there is growing support of buildings to be more serviceable after earthquakes. New cost effective techniques are required to strengthen the existing building stock and to enable a whole new generation of damage resistance buildings to be serviceable post-earthquake events. The New Zealand construction industry has a unique opportunity to lead the world in the design and construction of damage resistant buildings, if it is supported by adequate research.
Research components	The structural testing facilities in New Zealand are inadequate and better experimental testing facilities and the associated computational analysis tools are required. Testing facilities are needed to enable the development of new techniques and materials, to test innovative new building structures, and to allow practising structural engineers to create trial prototypes of their new designs.
Theme 2 **The goal is to improve techniques for retrofitting earthquake resistant techniques to underground infrastructure**	
Importance to New Zealand	The Canterbury earthquakes have demonstrated that the recovery times for essential underground infrastructure can be very lengthy, and the long restoration times have had dramatic and far reaching social and economic impacts on residential communities and on businesses in Canterbury. There is a need to address this issue across New Zealand, and to develop cost effective and

	affordable engineering techniques to improve the resilience of underground urban infrastructure.
Research components	There has been little or no research undertaken in New Zealand on this matter. GNS have analysed recovery times using overseas data for Wellington and the Hutt. MBIE has recently commissioned Opus to research the performance, and resilience of underground utilities (water infrastructure) under seismic loading within the Christchurch area and for national applications. As a result of this research recommendations and guidelines will be developed to enable New Zealand to be able to minimise disruption and increase the 'bounce back' capability of communities after a seismic event. Following on from this work, research on cost effective retrofitting techniques is needed to enable the findings of the performance research to be implemented widely across New Zealand communities that are in varying financial circumstances, a number of which have declining populations.
Theme 3 **The goal is to improve responses and recovery to future major catastrophic events of the scale of the Canterbury earthquakes**	
Importance to New Zealand	The Canterbury earthquakes have had major economic, social and environmental effects on Canterbury and have also had wider impacts national impacts. Events of this scale are a rarity in New Zealand, and it is important that we analyse the response and recovery in considerable detail, to draw as many lessons as we can from these catastrophic events.
Research components	To date there has been a “Review of Civil Defence and Emergency Management Response to the February Earthquake” and the focus of this was to review the management of the overall response of the range of agencies and organisations that were involved. Appropriately this was focussed on the response phase only and on activities and the co-ordination of agencies. The Canterbury Earthquakes Royal Commission has undertaken a detailed review of the specific buildings, and building design issues. This research proposal is to undertake a detailed methodological back-casting analysis of the various stages in the recovery and response phases of the two Canterbury earthquakes. This will investigate the economic, social, and environmental impacts, working backwards in sequence, and at each “mini” stage ask what were the capacity, capability, availability features and shortcomings that, if addressed, would have contributed to a better outcome? Issues that could be covered include understanding the logistical and community impact issues in the response phase, the red zone, the restoration of the local economy, residential housing repairs and availability, land use planning, the legislation enacted by Government and the agencies that were established.
Theme 4 **The goal is to raise the quality of engineering interventions to reduce risk from natural inundation hazards, whether these originate from tsunami, storm surge, tidal action, urban drainage failure, river flood or intense precipitation**	
Importance to New	Inundation is one of the most frequent natural hazards, and predictions are that climate change will increase the scale and frequency of inundation hazards. The

Zealand	benefits of having a sound flood estimation tools include: • Having a robust methodology for the assessment of flood flows for gauged and un-gauged catchments throughout New Zealand to support the design of structures in waterways and for the design of flood protection works. (Note: Many millions of dollars are spent within New Zealand on these structures every year) • More defensible and accurate flood-plain inundation mapping will be possible, which will better identify risks, or provide planning tools to minimise or avoid flood risks; The benefits of better coastal erosion estimates are: • Being able to respond to community concerns generated in coastal communities when coastal erosion set-back lines are proposed to manage coastal development, and also for infrastructure such as coastal roads and rail. There is a demand for robust and defensible estimates of future coastal erosion including both natural changes and susceptibility to the effects of climate change. Existing historical records indicate a great range of coastal responses to a single generating event, depending on the mechanics of wave transformation in response to local offshore bathymetry, resonance effects in harbours, onshore run-up, and the tide height and river flood status current as the wave arrives. The effects of these factors need to be separated so that the magnitude of each generating event can be isolated for ranking purposes.
Research components	The major research components are: • Updating of frequencies - nationally, the last update of river flood frequencies (average return period) and flood peak was 23 years ago in 1989 (McKerchar & Pearson). • Modelling of inundation hazards (floods, coastal storms, tsunami) – improving the accuracy and computing efficiency of inundation models that incorporate overland flows over complex topography and through built environments (buildings, roads, drainage, embankments) and develop into a coherent basis for design procedures. The models would: • correctly handle roughness at various scales from ground roughness to flows around large-scale buildings; and • incorporate scour and fill during the inundation process – especially for tsunami, dam breaks and major stop-bank breaches. • The hazards should be expressed in terms of overland flows reaching a defined protection perimeter for a given return period. The marginal construction costs of raising that perimeter could then be balanced against the benefits of extending the return period of the protection. • For each region, historical tsunamis and storm surges can then be ranked in a single series of incoming long waves, and assigned return periods according to a single scale. • The effects of climate change would then need to be applied by a standard projection based on the relevant intended design lifetime. Sea level rise would

	apply equally to both tsunamis and storm surges, but storm surges would need in addition some projection of changing storm intensities which may increase their ranking relative to tsunami events.
Research Gaps and Opportunities	Theme 4 gaps and opportunities The components of research infrastructure that are constraining progress on inundation hazard assessment and risk are: • High-resolution topography down to the low spring-tide mark – LiDAR or RadarSat imagery is being progressively collected around New Zealand, but it is patchy and really requires repeat surveys after 2-5 years to monitor change. • National building and infrastructure inventory – the lack of a coordinated central repository that characterises the built environment through various attributes is the single biggest factor that is holding up advancement of new quantitative inundation risk evaluation and risk mitigation tools such as RiskScape around each region in New Zealand. • The New Zealand Building Code requires that surface water shall not enter buildings from a drain, stream, river, lake or sea during a 1 in 50 year event. In current design practice, this means buildings near a major river are well protected, while buildings near the sea are not protected at all. • Similarly, the New Zealand Bridge Manual requires flood protection for bridges on major arterial routes up to a 1 in 5000 year event, but Jervois Quay through Wellington would be impassable in a 1 in 50 year harbour surge, while the Auckland North-West Motorway is already closed every year by the highest tides. • In each case the difference is that river flood statistics have established procedures for deriving return periods, whereas coastal flood events continue to be characterised by random observations, with no consensus on the translation of this data into design events of recognised return periods.

Entry ID	**400**
Big data strategies for tackling 'wicked' problems. - Climate change, sustainability and the effectiveness of emergency response systems are all part of the 'wicked' problems facing both our farms and cities in the 21st Century. Big data should now be used by the science community to solve these	
Theme 1 **Interoperability. - Creation of a flexible, extensible, and standard architecture that facilitates distributed and multi-platform computing for simulation models, integrates separate and remote applications, supports collaboration, and facilitates reuse for different problems**	
Importance to New Zealand	Due to the present lack of a coherent framework, different disciplines in their "silos" have developed simulation models of subsystems with the intent of solving whole of system problems (particularly for the farming sector). Although many are useful, they only tell part of the story of a complex system, and should not be solely relied upon as a decision aid for management and policy.

	We need to grasp the big picture, including the interrelationships between the causal factors characterising the wicked problem. What is needed is an architecture/framework which will support the simulated dynamics of the software "domain objects" representing the different system components where the combined ensemble will mimic the whole complex system. The complexity considered is the interplay of robustness (i.e. the ability to withstand trauma) and fragility (i.e. changes that can cause wild and catastrophic behaviour), resulting from the interdependent interactions of different components that make up the system. The adoption of a simulation interoperability framework will enable the synergy of distributed simulation models (where each model represents the operation of one part of the whole), thus enhancing the effectiveness of tracking wicked dynamics. The "plug and play" interoperability of these models/modules, should also be a nerve centre for collection, retrieval and storage of large volumes of disparate and incommensurable data, utilised by the simulation models. Another primary reason for such a framework would be significant cost savings that would accrue, and the ease of re-deployment in other regions, thus spurring wide and rapid adoption.
Research components	Component 1: Many simulation models for farming and forestry exist (in New Zealand), but what needs doing is moving away from the conventional discrete-time or continuous time equation models that are locked to a statistical bell curve for determining average trends. Instead use of decoupled software modules that allow extremes to be simulated, and allowing "online" model updates using data from wireless sensor networks and/or web services. Component 2: An important component of this development will be a Run-Time Infrastructure (RTI) which will provide a base into which separately developed simulations can be "plugged in", utilising different internal time management mechanisms to form the larger simulations of the whole system. Component 3: The complexity challenge of running a 'smart city' ecosystem would also benefit from a specific interoperability framework, given that the information and communication technologies (ICT) that interconnect the subsystems (such as security, energy, education, economy, health, government and mobility) have to be optimised on a day-to-day basis, as well as during major events or crises. Component 4: Scenario modelling is normally used to analyse systems by focusing on the average system behaviour, and minor perturbations from the average. To allow exploration of a much larger set of possible system behaviour requires multi-objective analyses. This enables identification of trade-offs among the objectives where increase in one objective does not result in an adverse decrease of another for a defined system search space. Therefore, a search space builder would be a vital component of this theme.

Theme 2 **Evolutionary Multi-objective Optimisation (EMO) and Multi-Criteria Decision Making (MCDM) - The objective here is to develop a portfolio of numerical techniques for determining multiple optimal options for improving the performance of complex systems based on many objectives (i.e. more than 10) and choosing the appropriate option based on preferences and values of the decision maker(s)**	
Importance to New Zealand	Systems optimised in the classical sense can be very sensitive to small changes, which are likely to occur anyway, given that the real world is dynamic, i.e. environmental parameters fluctuate, materials wear down, and markets are volatile. As such, search spaces for the classical optimisation techniques are informed by simulation models based on the statistical bell curve, which focuses on average values, and ignore the big departures from the mean. That means that the optimisation formulation is only correct for a limited time span. A better optimisation approach would be one that enables a high degree of robustness i.e. where the solutions and performance results remain relatively unchanged when exposed to uncertain conditions. Due to the complexity of the whole system captured in Theme 1: Component 4, through a simulation interoperability framework, the search space is “noisy”, i.e. exhibits real world variances and trends. Optimising such a search space requires a robust optimisation and in this case we advocate Evolutionary Algorithms (EAs) – they are well suited to solving not only large nonlinear optimisation problems, but can determine a set of optimal solutions where there are many objectives (more than 10). A choice of the appropriate solution is then made on the basis of values and preferences of the decision makers(s). The process of natural evolution inspired Evolutionary Algorithms, where the potential solutions are encoded as “chromosomes” that can combine and mutate. These individual chromosomes are selected for survival within a modelled “environment” that determines the fitness or performance of each individual in the population.
Research components	"Component 1: Many world problems presenting über-computational challenges (because of their large dimensional sizes and/or complex combinations of their numerics), have been solved using EAs. A classic example of this success in the mid-1990s was the design of the most fuel-efficient jet engine for the Boeing's 777 aircraft using a hybrid program consisting of EAs and expert systems called EnGENEous. This spurred the application of EAs in many different disciplines at a rate similar to “Moore’s law” (i.e. doubling digital device capability every two years). However, application has largely focused on 2-3 objectives. The innovations research here will be about combining the highly successful EAs with epigenetic abstractions, to solve multi-objective (more than 10 objectives) optimisation problems, which are a reflection of the real world. Component 2: The solution to an evolutionary multi-objective optimisation is a set of optimal solutions that show unique trade-offs amongst the different objectives. It is, therefore, imperative to have an explicit pathway for choosing a single

	solution for implementation, especially when there are many stakeholders/ decision-makers involved. This is a critical development because an involvement mechanism that will enhance the likelihood of stakeholders/decision-makers converging to a singleton that satisfies their combined preferences and values, will mean fewer chances of disagreement amongst stakeholders delaying the decision-making. The involvement mechanism will include developing social indicators that will be utilised in the context of multi-criteria decision-making (MCDM). MCDM will enable multiple decision-makers to choose from a pool of optimal solutions based on their aggregated preferences and values
Theme 3 **Visualisation - The objective here is the development and use of computer-aided and interactive images, diagrams, or animations to communicate or amplify cognition of large multi-dimensional results/solutions in a way that decision makers can absorb effectively, leading to concrete action(s)**	
Importance to New Zealand	Visualisation is strongly tied to assisting decision-making and it is a cognitive activity, facilitated by graphical external representations, from which people construct internal mental representation of the world. Computers may facilitate the visualisation process, although it still remains an activity that happens in the mind. For simple visuals, people are highly effective in recognising certain patterns and making quick effective judgments. However, multi-dimensional data information presents a challenge, which can be met with professional judgment. Professional judgment is defined here as the engagement of the mind in comparing and discriminating what is probable or improbable under the intellectual guidelines of a regimen of theory and practice. This is a skill acquired through interaction until it becomes intuitive. For example, flying an aeroplane cannot be mastered by just reading the flight manuals, but it is a “seat-of-the-pants” interaction until flying becomes intuitive. Therefore, a toolkit for professional judgment would look as follows: (a) Knowledge base of subject matter (where inadequate, expert opinion surveys may be carried out); (b) Interactive visualisation tools that transform information into knowledge; and (c) Intuition (which can come from previous experience, or experience derived from experimenting with (a) and (b)). For the reasons stated above, research and innovation in the field of visualisation (i.e. for the development of techniques and technologies) will aid in the effective consumption of big data to create value across sectors of the economy.
Research components	Component 1: This will involve the development of a visual analysis for big data prior to exploiting it for value creation. The novelty of this visual data analysis will lie in its ability to analyse the integrated big data as a search space for multi-objective optimisation (MOP). Such research will provide the ability to design for purpose, virtual search spaces, identified by unique statistical properties and yet-to-be-designed visuals.

	The ability to explore and visualise search spaces at the initial stage of designing MOP enables the designer to discover new search space structures, void of bias, with increased opportunities for discovering new and innovative solutions. As the search space becomes larger, it becomes increasingly important to understand what it means, before optimising to find the optimal solutions. Component 2: Visual representations must fit the underlying solution-data and also the complexity of the task. Therefore, the ability to visualise pre-processed multi-dimensional optimal solution spaces on a virtual reality (VR) immersive display is a critical part of amplifying understanding of multi-dimensional solutions. This research would entail building a VR system that would enable users to explore solution spaces interactively using motion-tracking technology. The technology allows for accurate measurement of the location and the orientation of one or several users as they move and interact in a simulated environment. The key to a sophisticated VR is this interactivity.
Theme 4 **Multi-Agent Systems - The aim here is to integrate societal multi-agent systems (MAS) with natural process models within the same interoperable simulation framework, for improving disaster response systems. MAS are the de facto models for problems characterised by decentralised control in dynamic environments**	
Importance to New Zealand	In the last decade, disaster preparedness from the threat of unexpected terrorist attacks, man made and natural disasters, has seen a huge investment in disaster response systems. However, improvements concerning the effectiveness of response operations still remain challenging. Improving information management during a disaster (through the timely collection, analysis, sharing and dissemination of data to the right people) will enhance the effectiveness of the response. To surpass existing systems is a difficult task, because an effective measure of improvement is notoriously difficult to test, as each disaster differs from another. The benefit of MAS is that they can simulate dependable patterns of collective human behaviour in a disaster situation. Simulations employed ahead of time, when there is the opportunity for reflection, are quintessential in improving disaster response. Central to these simulations is the coordination of a number of emergency responders with different priorities and preferences. As such a number of MAS models such as DrillSim, DEFACTO, ALADDIN, RoboCup Rescue and FireGrid, have been developed in different parts of the world for analysing specific aspects of disaster events. What is still lacking is a framework for interoperability between these models, to enable the combining of operations of all parts of the emergency response scenario. This would help to enhance and test the effectiveness of disaster response strategies. An effective, coordinated and timely response is a fundamental necessity in the face of any natural or man-made disaster, in order to reduce deaths, injuries, economic losses, social disruption, and/or contain secondary disasters that may exacerbate the scale of the losses.

Research components	Component 1: The time scales and costs involved in developing MAS models for all effective parts of disaster response are extremely high, probably enough to prohibit any research being done in New Zealand. The most effective way for us would be to build upon the successful research and developments already explored in disaster response management studies and state-of-the-art technologies elsewhere, and adapt existing MAS models to the New Zealand context. Component 2: With the models identified through Component 1, develop or adapt a software infrastructure designed to explicitly support modelling representations that can closely simulate the chaotic realities of social interchange and cooperative behaviours. This software infrastructure will still require an over-arching simulation interoperability framework that will support distributed dynamic representation of interlinked processes.
Research Gaps and Opportunities	Theme 1: Traditional linear thinking will not solve 'wicked' problems, with their complexity, interconnections and uncertainties. Yet in New Zealand funding is still being provided by both private sector and government for new attempts using linear thinking to solving such problems. However, what the existing simulation models will be useful for is as building blocks for analysing whole systems in a simulation interoperability framework, such as those being researched currently in Europe and the USA. Not only could their work help New Zealand science, but there are good opportunities for our scientists (in both universities and research institutes) to gain big data experience by collaborating and building on this work, to benefit both here and elsewhere. The current simulation models here are not yet designed to take advantage of big data, but collaborative work could get this process under way. As an initial step in getting our cities to be 'smart' New Zealand requires more simulation models in emergency response. Again we should build on overseas research with collaborative work on disaster response in four intertwined areas: • Damage assessment (i.e. the magnitude of disaster-related losses being identified); • Needs assessment (i.e. identifying incidents requiring response); • Prioritisation of response measures (i.e. prioritising a 'matched-required-response' to available resources); and • Organisational response (i.e. decision making behind the logistics of the deployment of emergency resources). Much of the technology required for all this decision making already exists. Making it interoperable would broaden the scope for intelligent and acceptable decisions immeasurably. In New Zealand science there are already a number of alliances between those in different institutions working on individual challenges in these areas. Theme 2: The classical EA is applicable to unconstrained optimisation problems. However, real world problems are generally characterised by multiple objectives

	that are conflicting and incommensurable, heavily constrained, and too large for reasonable computing resources. Thus the classical EA is a mixed blessing, introducing promising offspring through generations, whilst at the same time potentially violating many of these constraints. It takes considerable computation time to satisfy these demands. The conventional wisdom is to include additional problem-specific knowledge, which tends to undermine the metaphor of natural evolution. This is an opening research area where New Zealand and United States scientists are already working together to find a generic representation of the epigenetic metaphor that, when combined with the classical EA, can mean substantial reductions in computational time without sacrificing the quality of the solutions. Management science in New Zealand is still in its infancy. Critical developments have occurred in Europe and United States with the development of the most widely used MCDM tools such as Promethee and ELECTRE. These assist in the ranking of a finite number of decision alternatives, each of which is described in terms of different characteristics (aka attributes, decision criteria, or objectives), which must be taken into account simultaneously. However, the Achilles heel of these tools is that the initial finite alternatives are not optimal, which compromises the outcome of the MCDM analyses. An active area of research is combining EMO and MCDM. As far as we know there is no research in this area in New Zealand, but again there are firm collaborative work arrangements between some New Zealand and United States scientists in dealing with this problem. Theme 3: Visualisation is a growing area of research, as companies continue to churn out volumes of transactional data, social media sites continue to allow billions of people to interact, and scientists collect more biophysical, economic, and social data. Given that every wicked problem is essentially unique and novel there is no “one-size-fits-all” visualisation tool, but rather a vast array of options suited to the problem. However, when using big data to solve wicked problems, the generality comes in the fact that we are dealing with multi-dimensional data. Visualisation labs will be an investment of the future, which decision-makers will be able to use to interact in their virtual problem spaces and solution spaces, to make better informed decisions. Google now is providing cheaper specifications for building such visualisation labs. HIT Lab NZ is at the forefront of this development, although there is much work to be done in research and development of unique visualisation software tools for specific problems. Theme 4: With the plethora of MAS models being created overseas for emergency response in planning, training, and real-time disaster response, interoperability has become the focus for research in an environment that supports distributed and dynamic representation of interlinked processes. New Zealand has skills in MAS models that seem to have lain dormant in the social sciences discipline. These skills need to be drawn into the applications arena for solving complex problems and build on already existing overseas MAS models. In addition, wireless sensor data, satellite imagery and weather, information from

	mobile devices such as mobile GIS (for updating spatial data) and text messages (for geo-location and semantic annotation) have now become part of big data used in disaster response situations, adding to the quality of information, and ultimately effectiveness in response time. However, a seamless link of all of the above is still elusive, and New Zealand scientists will need to partner with overseas scientists in developing these specific interoperability frameworks. Revolutionary advances in disaster response systems have seen an unprecedented development in MAS. MAS have been advocated as the most appropriate means of finding solutions to a specific domain of real-world problems through their ability to incorporate human behavioural aspects. They encapsulate a number of "agents", each with their own aims, objectives, and resources; where an agent is a software program that can act flexibly to achieve some global objective(s) in coordination with other agents. An agent is characterised by autonomy, reactivity, proactivity and an ability to negotiate with other agents. These agents coordinate to reconcile their constraints and preferences, in order to maximise some global objectives, within a dynamic and uncertain environment.
Comments	Theme 1: There are currently negotiations taking place between Scion, BEACON Centre (Bio/Computational Evolution in Action CONsortium, Michigan State University) and the international organization Living PlanIT, to use Living PlanIT's Urban Operating System (Urban OS™) as a research platform for 'smart farms' and emergency response. Urban OS™ is a software platform designed to accelerate the development and deployment of urban technology and "connected devices". It is similar in concept to iOS or the Android operating systems for smartphones and/or tablets, in which Apps are written by developers for subsequent user download and use; named "PlaceApps" for the Urban OS™ ecosystem. The premise of this bold innovation is a smart infrastructure with cloud-enabled sensors and actuators, which can be accessed by urban systems and other connected devices. It would be a wise move for New Zealand science research to build upon the successful research and developments already explored in management studies and state-of-the-art technologies developed both here and by others working in this area. It is important to note that Living PlanIT was selected as one of the World Economic Forum's Technology Pioneers of 2012. We would then have produced a system which would not only hugely benefit planning for land use management, emergency management and many other spheres, including climate change adaptation within New Zealand, but would be exportable to many other countries which are crying out for a system like this. Theme 2: Planners and systems which continue to isolate the three levels (strategic, tactical and operational), and then attempt to marry them with regulations, are losing the opportunity to allow themselves to work with multiple options, and to deny those who have to work with their decisions a chance to make choices on how they will comply. New Zealand has already partially embraced the concept of 'triple bottom line', (involving economic, environmental and social elements) in its Resource Management Act. These elements already underpin much of today's planning,

	and will increase in importance as other issues arise. A planning system which instead uses technology to allow for evolutionary multi-objective optimisation provides the ability to consider both a long list of objectives for any problem, and also to consider a huge range of criteria during the decision making process. Such systems are far more likely to meet with overall support from those who will be affected by them, and can also be used to consider (in the case of land use planning) large areas, such as catchment by catchment, rather than farm by farm. Theme 3: Decision makers at both ends of the spectrum (authorities and those who will be affected by their decisions) find it difficult to fully comprehend the multiple outcomes of complex decisions. Being able to see these outcomes as visualisations, both of immediate and long-term changes, adds a whole other level to their competency. The significance of this capability for preparing simulations for emergency management, climate change adaptation and land use planning is huge. For emergency management, being able to visually recreate disaster events and then consider better potential responses, could not only save lives, plan resources, but also utilise available resources more effectively as and when required. The implications for climate change adaptation are just as great, allowing simulations to include all aspects of change, and the anticipated timing of each change. In land use, this capability would not only allow regional councils to fully investigate the implications of their decisions, but would also allow landowners to make individual decisions on land use, while still complying with overall rulings. Theme 4: Note also that emergency response is complicated by Black Swan events (i.e. the unexpected or hard-to-predict events that have significant consequences), and carry the hallmark of a wicked problem. Due to complex interdependencies, the effort required to solve one aspect of a wicked problem may reveal or create another. Wicked problems tend to defy resolution because of enormous dependencies, uncertainties, circularities, and conflicts between stakeholders implicated in any effort to find a solution, and therefore require timely adaptive responses to the situational changes. Therefore, helping decision and policy makers tackle wicked problems, yoked with Black Swan events, will stretch the bounds of science to the limit, in recognition of the complexity and uncertainty over long-time horizons, combined with the need for short-term management interventions.

Entry ID	**433**
	Resilience To Hazards / Coping With Natural Disasters
Summary	This challenges proposes a research programme into the resilience of a wide range of technological infrastructure, including electricity and communication, during and after natural disasters

Theme 1 Technological Infrastructure As An Economic Weak-Point	
Importance to New Zealand	Economic and personal well-being is dependent upon technological infrastructure, at levels as basic as the provision of electricity and communication. Such systems are both highly sensitive to natural hazards and vital for coping during disasters People's first views of Natural Hazards are inevitably dominated by earthquakes, tsunami and volcanic eruptions. However, the possible hazards are much broader than this, and include hazards which affect peoples' wellbeing by damaging core economic infrastructure (without necessarily collapsing buildings or bridges). An additional vital factor is the resilience of the technological infrastructure used to cope during and after a natural disaster, whether it is through communication, sensing, or provision of electricity.
Research components	A combination of fundamental science and applied engineering is required to understand the threats to our technological infrastructure, develop a more resilient system, and ensure we can apply these tools whenever needed. For example, understanding how external natural drivers from the Sun can impact and disrupt space and ground based technology is an important issue — as it can damage electrical infrastructure/power distribution, communications systems and Earth-orbiting satellites; the same geomagnetic storms which lead to auroral displays, have also caused damage to South Island transformers and stressed the Transpower network, and such recurring natural events need scientific consideration alongside terrestrial natural hazards the public are more familiar with.
Comments	This is an important Challenge facing all of New Zealand. Although the University of Otago has highly skilled expertise within geology, surveying and geography that is of immediate relevance to hazards such as earthquakes and volcanic eruptions, these Themes will be more comprehensively framed up by other providers. Otago has therefore restricted its submission to profile one key, but overlooked dimension — that of the resilience of New Zealand's technological infrastructure.

Entry ID	**445**
Communities resilient to biotic and abiotic hazards	
Summary	This challenge proposes that research into improving our built and local natural environment will lead to greater resilience to natural and man-made hazards, higher productivity (human and resource), stronger social outcomes (e.g. health) with spill-over benefits in new exportable products. Research is needed to develop tools to predict geological hazards, forecast the impact of climate change, develop 'new build solutions' which deliver affordable, healthy homes with low environmental footprints, and the develop new manufacturing solutions

	for bespoke buildings but that capture the opportunities of mass manufacturing – including the ability to deliver resources (such as water and energy) to small communities.
Importance to New Zealand	The New Zealand environment is subject to geological disturbances, and extreme climatic events which are increasing due to climate change, fire and exposure to biological pests and diseases which threaten our primary industries - the base of our economy. In addition New Zealand houses are typically high cost (compared to OECD standards) and below WHO guidelines for health. Recent events (earthquakes and weather-tightness) demonstrate that New Zealand needs a rethink in its build design solutions across the value chain and that such a rethink must take into account both the immediate natural environment of such buildings and the communities in which they operate. New Zealand's 'wicked' combination of high environmental risk (geological, climate, fire and biotic) and scattered resource base (our farms, forests manufacturing industries , energy and water) is a high risk environment upon which to build a robust production base and sustain communities that are at the heart of our nation's production. Should we address this, then the successful outcomes will include: • Increased human productivity due to health and social improvement and more resilient communities. NZ currently has a low human productivity level compared to OECD indicators. • Strengthened social outcomes • Improved security of our national production base to sustain productivity across our nation in the communities that underpin our biological industries. • New product opportunities: New Zealand solutions (building, IT based products and distributed systems) will lead to new export industries to meet global needs for affordable, low environmental impact and resilient buildings, predictive tools and capabilities to support our communities.
Theme 1 **Readiness – forecasting hazards**	
Research components	Forecasting hazards, including risk pathways: • Geological - tools to predict hazards • Climate change(to allow for interventions to reduce the impact, and accommodate and mitigate those changes); • Fire - tools to predict potential fire burden (rural and structural); • Biological agents
Theme 2 **Reduction of the impact of hazards (including mitigation)**	
Research components	Reduce impacts of hazards: climate change; geological events; fire (rural and urban); biological agents; disease forecasting (risk pathways); land burden; waterways

Theme 3 Resilience	
Research components	Future systems: • Resilient Communities (urban design to create best interactions between the built environment and the natural environment to promote community well-being and increased human productivity) • Resilient buildings and infrastructure (build systems that are affordable, minimise environmental impact and enhance the health and productivity of their inhabitants) • Natural environment resilience (a sustainably-productive environment - cross over to land/water/manufacturing) • Community preparedness and resilience to fire; and use of fire in rural settings as an alternative to chemical control for pest management.
Theme 4 **Value creation**	
Research components	New manufactured outcomes: • New build solutions – new systems and processes based on New Zealand resources that deliver affordable, healthy homes with a low environmental footprint. • The new build value chain – development of new manufacturing solutions that deliver bespoke buildings but capture the opportunities of mass manufacturing – including the ability to deliver resources (such as water and energy) to small communities • Exportable building systems to support international aspirations for sustainable and resilient shelters • ICT tools for forecasting, hazard mitigation and visualisation and modelling • Distributed manufacturing systems to sustain local value creation
Research Gaps and Opportunities	Currently there is activity in most of the above but little cross interaction. Proactive research in new build solutions, and its consideration as part of a wider value chain including its interaction with people and their behaviour, is barely touched on, or not undertaken, in New Zealand at all. Important underpinning competencies are not obvious in the above including complex analysis, data mining, and human factors.

Entry ID	**463**
Increased Resilience to Natural Hazards. Goal: To increase New Zealand's economic and social resilience to natural hazards, by quantifying the risk to production, infrastructure and community activities, based on accelerating the understanding of hazard processes, impacts and mitigation options	
Summary	The goal is to increase resilience to natural hazards. Themes include understanding why natural hazard events occur where they do, their frequency

	and magnitude, in order to mitigate their impacts on urban areas and rural economy and improve hazard event forecasting, using sound engineering principles to improve damage control for new buildings/infrastructure and establish mitigation and strengthening provisions for existing built environment, understanding social factors that determine how individuals, communities and organisations interpret risk and incorporate risk in decision making, developing risk models of various possible natural hazard impact scenarios based on a national dataset of resilience of communities and buildings.
Theme 1 **Developing quantitative frequency-magnitude and forecast models of natural hazard events**	
Importance to New Zealand	Natural hazard events pose the most likely destructive impacts on New Zealand, in terms of casualties, infrastructure destroyed and social well-being diminished (http://www.dpmc.govt.nz/node/930, page 22). We are vulnerable to a range of hazards, from relatively frequent flooding, to infrequent large earthquake events. To mitigate these impacts (i.e., reduce the social and economic cost to the country) it is necessary to understand why extreme wind, snow, hail, river floods, coastal erosion and storm surge, volcanoes, earthquakes, landslides, and tsunami occur where they do, at what frequency, in what magnitude range, and how they impact urban areas and the rural economy. From the fundamental understanding of individual hazard processes, we can make quantitative estimates of each hazard and associated cascade effects (a “multi-hazards” approach) using probabilistic modelling methods for individual, and integrated perils. These models provide the hazard component of the risk equation. A key element to reduce impacts is the ability to forecast hazard events when these are likely to exceed current mitigation. This is particularly applicable to weather, flood and coastal storm surge hazards, where more accurate forecasts, especially of flooding, will both provide advanced warning and model, in real time, the impacts, and guide emergency response. With improved understanding of the driving forces of geological hazards, time varying forecasts of when these perils may strike is becoming a reality. Forecasting weather-related hazards is further advanced than for many of the geological processes although good progress is being made in forecasting earthquake aftershocks and volcanic eruptions.
Research components	Key research questions for natural hazards quantification in New Zealand include: • What are the key processes driving weather-related hazards (storms, floods, coastal, maritime, drought, snow/avalanche/hail, landslides), what are the full range of magnitude and frequency characteristics in different areas, and how can we develop improved predictive models • How can we improve flood forecast accuracy and forecasts of inundation depth in advance of and during flood events? • How can we better simulate storm surge and coastal erosion/accretion in the near-shore and foreshore, and the evolution of coastal margins? • What is the average and maximum size, and timescale typical of different types of volcanism? What monitoring tools are most useful at different types of

	volcanoes, and how can modelling of magma genesis and volcano plumbing systems inform forecasting? • Can we determine the thresholds for landsliding related to earthquake and rainfall triggers, and what controls the variation in occurrence and size of landslides through time? • Do undersea landslides and volcanoes contribute significantly to tsunami hazard? Are debris and pollutants caught up in tsunami inundation an under-appreciated component of tsunami hazard? How effective are typical natural coastal landscapes at buffering tsunami attack? • Can we combine past and current records and effects of earthquakes (instrumental catalogue, historical accounts, active faults studies, GPS), to more accurately forecast future events? Can Canterbury and other data inform the relative importance of earthquake source characteristics, the travel path effects, and the influence of near-surface soil properties, on earthquake damage?
Theme 2 **Determining building and infrastructure performance that provides resilience at acceptable levels of risk**	
Importance to New Zealand	Enhancing the resilience of our communities to the effects of natural hazard events, and thus reducing the social and economic cost, involves application of sound engineering principles to address both building collapse and damage control and the preservation of key lifelines in order for them to remain operational. Engineering research will provide a performance-based framework within which both life safety and operational functionality are achieved in a cost-effective manner. When implemented, community impacts experienced during an event will remain within tolerable limits and people will, in the main, be able to continue living within their homes. Critical services, although they can be expected to be disrupted, will be restored, within acceptable timeframes to avoid lengthy societal disruption with consequent economic impact. A performance-based framework will be used to design for damage control to both new buildings (and infrastructure) and to establish mitigation and strengthening (retrofit) provisions for our existing built environment, including buildings, bridges, dams, water supply and waste networks, and energy and communication networks.
Research components	Research questions for resilient engineering and infrastructure research include: • How can we develop a suitable, probabilistic, performance-based engineering framework that will ensure existing and future buildings and infrastructure meet target performance levels so as to enable rapid and cost-effective restoration of fully functioning communities following a natural hazard event? • How can we determine how buildings can be economically designed, built and/or retrofitted so as to match the societal performance expectations, both during and following, a natural hazard event? • How can we create methods to design, build and/or upgrade critical infrastructure and lifelines systems so as to maintain their life support function

	following a natural hazard event, being cognisant of the high level of interdependency between such networks? • How can alternate approaches to performance based design be used to evaluate the current building and infrastructure stock and retrofit options to determine effective risk treatment against expected future occurrence of extreme winds, tornadoes, flood, earthquakes, tsunami, and volcanic ash?
Theme 3 **Social factors that determine resilience**	
Importance to New Zealand	Developing a fuller understanding of the way individuals, communities, and organisations operate within complex natural and social systems is necessary to best prepare for and respond to the adverse impacts of future natural hazard events. Understanding how risks are interpreted and how these interpretations inform decision-making and actions is an important component in developing the knowledge base in this area, and underpins current research in societal resilience. Decision-making, particularly under conditions of uncertainty, can no longer be adequately accounted for using traditional models of 'rational choice'. Instead, attention needs to be paid to how risk interpretations are shaped by individual and collective experience, values, cultural beliefs and interpersonal and societal dynamics. Resilience is a function of both hard engineering (Theme 2 above) and human interaction within that environment. This research will provide an understanding of the characteristics of a well prepared, adaptive and therefore resilient society. Application of this evidence based information will enable solutions that align with the social factors that increase community resilience.
Research components	Key research questions for understanding societal resilience include: • What societal factors and strategies enable strong communities that are resilient to the impacts of natural hazards? • What factors contribute to cascading failure across societal sectors, networks and groups and how can these be mitigated? • What is the vulnerability of the economy to natural hazards and how do factors such as the economic structure, stage of development, prevalent economic conditions and the policy environment play a role in that vulnerability? • What trends and emerging issues in our society influence vulnerability and resilience to natural hazards? • What evidence-based strategies for improving resilience are most likely to be adopted in governance, planning (including land use), policy, organisational, economic and legislative frameworks? • What policy and procedure opportunities exist that will afford integral understanding, application, management and utilisation of disaster risk reduction science within planning, risk and adaptive management processes? • What improved communication methods and tools will facilitate the transfer of

	hazard and risk knowledge to stakeholders? • How effective are emergency management procedures and crisis management practices for optimising societal response to warnings and hazard events? • What are the steps by which society transitions, recovers and adapts (and how can these be enhanced) after the disruption caused by natural hazard events?
Theme 4 **Risk models of natural hazard impacts**	
Importance to New Zealand	The physical, social and economic impacts of natural hazard events are acceptable only when they remain within tolerable limits. Thus, important products of risk modelling research are suites of alternate scenarios informing, in a socio-economic context, definitions of acceptable and tolerable. No such basis for risk management in New Zealand is currently available. Aspects of impacts that must be modelled include physical damage, direct and in-direct losses, casualties, transport, business disruption (including the primary sector) and social disruption. Comparing risk posed by different natural hazards in a consistent way that incorporates a range of potential impacts and consequences provides the quantitative basis for selecting mitigation options and response actions to improve resilience. A nationally consistent dataset of exposure and related vulnerability of the built environment and social characteristics of communities, coupled with probabilistic and scenario based hazard simulations that include cascading hazard impacts and inter-dependencies, enables proper comparison between (equally likely) hazard events. Using an enhanced RiskScape tool (see gaps and opportunities) quantitative models can inform options to: a) help to prioritise investments in specific measures that reduce the risk (e.g., earthquake strengthening of buildings, upgrading stop-banks); b) identify appropriate land-development planning that is truly cognisant of the level of natural hazard risk; c) deliver natural hazard risk models to the insurance industry to reduce premium for uncertainty and provide an improved technical basis for underwriting, and; d) prepare effective emergency management response plans and regular exercising using realistic risk scenarios.
Research components	Key questions for quantifying natural hazard risk include: • Which natural hazards pose the greatest risk to our communities i) on an annual basis, ii) on a moderately long term basis (5-10% probability over 50 years)? What gaps in individual hazard knowledge need to be addressed to enable their intensity to be modelled for single sites, cities, or nationally? • How can we include consequential hazard effects (e.g. fire following earthquake, debris laden flood flows, earthquake-induced ground deformation, climate change driving changed weather hazards) in probabilistic impact models? • How best to incorporate the cost of social and economic disruption into loss models? • How can supply chain disruption be incorporated into impact models?

	• How can we modify our existing community models to reflect the society of tomorrow (e.g. allowances for green-field growth, urban densification, new building technologies and changing societal expectations)? • Can we model the impact of future events by consideration and adjustment of past ones (i.e. what is needed to incorporate variations in time and space)? • How can indirect consequences of hazard events be anticipated and included within loss models? • How can uncertainty in loss models be quantified and expressed most robustly, and represented in alternate mitigation options (perhaps incorporating weighted decision tree options)? • What are the most appropriate formats for natural hazard risk impact models so as to ensure most effective utilisation by research users?
Comments	Applying natural hazard research to demonstrate and promote National Risk Management action Natural hazards research in New Zealand is better integrated following the formation in 2009 of the Natural Hazards Research Platform. However, the Canterbury earthquakes exposed the need for all aspects of risk management to be better integrated. Recent engagement with re-insurers – who together cover two-thirds of the insured losses in Canterbury - has revealed a thirst to understand what New Zealand is doing across all stages of risk management: identification, assessment, mitigation, adaptation. Giving industry confidence in our approach to national natural hazard risk management is critical for New Zealand's economic resilience. We propose to (1) accelerate development of the RiskScape modelling tool, to complete its application across all stages of risk management, and (2) form a focused team to meet New Zealand's risk management knowledge transfer needs internally and externally. Interested parties include: • Central government agencies, including MBIE, Treasury & MCDEM. • All regional & district councils. • EQC. • New Zealand Transport Authority. • Insurers, reinsurers, and their technical advisors. • Business, including banking, construction, and finance. New Zealand can become a world leader in the emerging reinsurer-led discipline of National Risk Management. Modest investment ($3M p.a.) for improved and communicated hazard risk impact models has the immediate potential, in just the insurance sector, of significantly reducing New Zealand's c. $400 million annual reinsurance spend on earthquake cover, and reducing the likes of the $30 billion insured losses resulting from the Canterbury earthquake sequence. Fuller resilience benefits across all aspects of New Zealand society and economy will flow. Additional Comments: The research proposed is well aligned with the National Science Challenge

	concept since: • This is a National Challenge that is directly addressable through additional science. New Zealand has a well-documented hazard history and the Christchurch earthquakes have highlighted gaps in our knowledge and tools that require initiatives beyond business as usual. • There are national scale benefits. Long term resilience of communities and infrastructure depend on quantifying impacts to inform risk reduction, speed recovery following events, and provide a sound basis for insurance. • The Natural Hazards Platform is of national scale - it currently includes or contracts the majority of hazard research teams in New Zealand, complemented by international links to best practise. • The Platform is already formed, working and collaborating, has shown how responsive it can be following the Christchurch earthquakes, and can start and deliver new work quickly.

Entry ID	**466**
Safe, Healthy and Resilient Communities	
Summary	The goal is to build safe, healthy and resilient communities with a research programme focusing on what makes cities strong and resilient to future shocks, and ways to further develop a strong sense of community

Entry ID	**482**
Infrastructure, hazards and us	
Summary	The goal is to improve the development of infrastructure in New Zealand. Themes include investigating what infrastructure is needed to create healthy and productive communities in the future (e.g. housing, building, transport, water systems), developing an evidence based process for decision making regarding economic management infrastructure, developing a model to evaluate the social and economic trade-offs of infrastructure developments, identifying and developing models to quantify the effects on infrastructure of future hazards in New Zealand
Theme 1 **How do we understand current and future infrastructure needs and resources**	
Importance to New Zealand	Establish a dynamic matrix of infrastructure type against current needs over various timeframes (10, 20, 50 100 years) and against the resources required, and use as a baseline to measure current state and future progress
Research components	10.1.1 Identifying needs for healthy and productive communities. Focus on housing and buildings including affordability issues, healthy houses, risks (eg leaky buildings), schools, prisons, hospitals, heritage and social infrastructure 10.1.2 Identifying infrastructure needs for healthy and productive communities. A

	focus on lifelines (transport including roads, water, air travel and aggregates), and impact on the economy and communications (including ICT), electricity distribution, water, waste water systems etc.)
Theme 2 **Evidence-based decision making for economic management of infrastructure**	
Importance to New Zealand	Establish a robust, documented decision-making process for making infrastructure economic management decisions and use as a baseline to measure current state and future progress
Research components	10.2.1 Conducting robust whole-life value analyses (including future generation analysis, lifecycle analysis) of core national infrastructure and model possible impacts of different development options 10.2.2 Developing improvements to socio-economic decision-making for future infrastructure developments
Theme 3 **Developing and managing the opportunities, and economic and social trade-offs**	
Importance to New Zealand	Establish a usable integrated management model incorporating infrastructure systems against economic and social trade-offs and use as the basis for evaluating future infrastructure developments
Research components	10.3.1 Modelling of impacts of infrastructure changes over time 10.3.2 Identifying society acceptance of trade-offs taking a multi-stakeholder approach
Theme 4 **Understanding New Zealand's current and future hazards, their risks and impacts**	
Importance to New Zealand	Establish a dynamic matrix of hazard type against risks and impacts over various timeframes (10, 20, 50 100 , 1000 years) and use as a baseline for measuring current state and future progress
Research components	10.4.1 Identifying current and future hazards, including climate change, pandemics, geological, weather, flood, coastal and fire hazards affecting New Zealand society, including those that affect the built environment and their supporting infrastructure 10.4.2 Developing measuring tools and predictive models to identify the degree to which different hazards can impact on society 10.4.3 Understanding the performance of community resilience, organisational resilience, buildings and infrastructure resilience.
Research Gaps and Opportunities	New Zealand has a large land and sea mass relative to its population and is subject to a wide range of common and potentially catastrophic natural and other hazards. Providing physical infrastructure that meets society's expectations and supports resilience to hazards and other catastrophic events from such a small population base is thus economically challenging. Designing infrastructure that meets New Zealand's future needs is critical to our future prosperity and wellbeing.

Entry ID	485
Fire, a natural hazard: resilience and prosperity.	
Summary	The goal is to increase resilience to, and effective use of, fire hazards. Use natural hazard benefits to aid recovery by progressing science and technology for community and environmental resilience. Herein fire is a proxy for all natural hazards; it is a devastating force and a beneficial management tool Themes include advancing risk assessment systems for wildfire and expanding knowledge of impacts of fire on New Zealand's ecosystems, enhancing resilience and adaptive capacity of New Zealand communities to rural fire, e.g. researching Māori views of fire hazards, investigating the human dimension of hazards as land management tools to enhance use of fire as a viable tool for agriculture, forestry and pest management, developing novel technologies for enhanced hazard awareness and accessing hazard benefits, e.g. situational awareness of developing fires in the landscape and creation of advanced fire suppression technologies, future-proofing fire hazard management for changing climate, land use and human dimensions
Importance to New Zealand	Use natural hazard benefits to aid recovery by progressing science and technology for community and environmental resilience. Herein fire is a proxy for all natural hazards; it is a devastating force and a beneficial management tool.
Theme 1: Advance devastating force risk assessment **Advance risk assessment systems through improved understanding of destructive hazards. Integrate wildfire risk with other hazard assessment tools and through science, expand our knowledge of the impacts of fire on New Zealand's productive and natural ecosystems.**	
Importance to New Zealand	Despite considerable research on describing New Zealand's fire climate severity, and availability of some statistics on the occurrence of rural fires, the risk from wildfires in New Zealand is still poorly understood. Wildfire risk is a combination of many complex factors, including weather/climate, fuels, terrain, ignition sources and values-at-risk. With >98% of rural fires in New Zealand resulting from human-causes, social factors such as population demographics and land use are also especially important. Development of existing fire risk assessment systems in New Zealand over the past decade (such as Wildfire Threat Analysis), while significantly improving assessment of wildfire risk, are still highly subjective and only poorly correspond to the joint AS/NZS 31000 risk management standard definition for risk based on the combination of likelihood and consequence. There is a need to improve the assessment of wildfire risk in New Zealand and to align it to the risk management standard by bringing it into the same framework that exists for other natural hazards. In addition, impacts of fire on New Zealand's productive and natural ecosystems are not fully appreciated, and poorly quantified. There is also a need for improved information on direct and indirect impacts of fires, both economic and non-economic (including intangibles), for New Zealand ecosystems.
Research components	Component 1: Improve understanding of risk: Bring wildfire risk into the formalised risk definition by understanding the likelihood of the hazard occurrence

	and the consequence of the hazard. Align and integrate wildfire hazard with other natural hazard risk systems (e.g., RiskScape). Develop coupling between two or more hazards within the risk assessment system to assist with decision-making should hazards occur consecutively. Component 2: Improved quantification: Determine the direct and indirect impacts of wildfire in New Zealand. Total impact of wildfire varies based on region, ecosystem, economic base, and source of livelihoods.
Research Gaps and Opportunities	Gaps exist within current hazard risk assessment systems: in the inclusion of wildfire risk, particularly using a formalised description that aligns with the risk management standard (AS/NZS 31000); in progressing existing wildfire systems towards reliable systems/tools for assessing wildfire risk; and in fully understanding the direct and indirect effects (due to wildfire. New Zealand can capitalise on the opportunity to integrate assessment systems for different natural hazards, allowing for a comparison of risks and identification of cumulative effects associated with different hazards (e.g. effects of drought, wind or snow damage on wildfire risk). Further opportunity will arise from these integrated systems to assess consecutive natural hazard impacts, which is important as one natural hazard is often followed by another (e.g. volcanic eruption and landslide, or wildfire and dust storm). The opportunity exists to develop improved methods for quantifying direct and indirect effects, including economics and less tangible values for New Zealand environments.
Comments	Natural Hazards Platform research partners (GNS, NIWA, Opus, Massey, Auckland & Canterbury universities), including RiskScape developers Economists (BERL), social hazards researchers
Theme 2 **Develop science to enhance community resilience and adaptive capacity to rural fire**	
Importance to New Zealand	A key focus of international natural hazards research dwells on human vulnerability which is influenced by social characteristics within the changing climate, land use and social environment. Least vulnerable communities are those characterised as resilient, or having the ability to learn and adapt in response to hazard events. Worldwide, communities have taken steps to increase physical and social preparedness. New Zealand rural communities present a particular challenge that warrants a focus on communities due to underestimation of wildfire risk. This has led to low levels of preparedness, vulnerable communities, and therefore a lack of community resilience to wildfires. Research into improving community preparedness for wildfires will bring important lessons that will help to enhance resilience and increase adaptive capacity of communities for all natural hazards. The New Zealand Fire Service has identified Māori communities as at-risk groups for adaptive capacity for the wildfire risk (TNS, 2010). A specific study is required to understand use of fire in Māori rural communities, how fire is regarded and used as a tool today and Māori perceptions of fire as a natural hazard/risk

	within the context of the mātauranga theme of Vision Mātauranga. In New Zealand, most known wildfires are escapes from prescription burning. Research is required to determine the human dimension of using fire as a land-management tool, the view of the role of fire to livelihood, and the community role in developing fire for land management applications.
Research components	*Component 1: Build on existing community frameworks* Progress research to determine strategies that build on existing community frameworks and networks to enhance community resilience and adaptive capacity to hazards. This builds on existing community strength itself and leads to increased community preparedness. Through existing community frameworks planning strategies can be formulated and community preparation can occur before hazard events. Wildfire as a hazard can be addressed within the wider natural hazard context through development of the wildfire component, which will enable communities, regional planners and fire managers to collectively mitigate against increasing risk of natural hazards. *Component 2: Māori traditional and present day views of hazards* Research is necessary to fully understand the views of Māori communities and land owners towards natural hazards, including fire in the rural landscape. This includes the benefits of hazards, such as the use of fire as a land management tool for food crops, e.g. clearance for kumara beds and understanding Māori perceptions of fire as a natural hazard/risk. Understanding is needed to explore changing views of fire and other hazards with increasing land-ownership of forest lands and other assets. *Component 3: Human dimension of hazards as land management tools* Explore the human dimensions of people benefitting from natural hazard (i.e., crop growth after a flood) including those using fire as a land management tool.
Research Gaps and Opportunities	There is a large gap on developing generalised community preparedness that is applicable to all natural hazards due to the natural tendency for communities to focus on the most-recent or most-likely hazard. For example it is difficult for most temperate climate communities to view wildfire as a hazard, yet wildfires do occur in this climatic zone and often they are very destructive. For example fires have impacted on rural communities in recent years in areas such as in the rural-urban interface of West Melton, Nelson and Wellington and more rural communities near Queenstown, Wairoa and the Karikari peninsula, Northland. New Zealand can capitalise on collaborations with international researchers working to address this issue in North America and Europe. Lessons learned from those regions of the world can be applied and progressed in New Zealand.
Comments	Collaborations with community led groups and networks within case study areas. Partnerships with iwi for Māori focused research. Reference: TNS (2010) Fire knowledge survey. Report prepared for the New Zealand Fire Service. TNS Conversa.

Theme 3 Accessing the benefits of hazards - enhance the use of fire as a viable tool for agriculture, forestry and pest management	
Importance to New Zealand	Hazards are destructive forces that place communities in turmoil. Recovery from hazard occurrence is difficult. Developing science and technology to assist communities in accessing the benefits of hazards (i.e. shifting volcanic ash to nutrient soil depleted regions; planting crops at the right time after a flood) will aid recovery. Fire, although a hazard when escaped, is a cost-effective, sustainable, land management tool compared to mechanical or chemical methods. Fire is considered a more natural process and therefore a green alternative to chemical control, despite the smoke emissions. The high number of escapes from land clearing burns-turned hazard exemplifies the need for advancement of prescription fire science, accessing the benefits of fire in New Zealand environs. It also exemplifies the need for application tools that assist with the 'go/no-go' burn decision process. New Zealand prescription fire-science and technology development is lagging behind its international partners who use fire as an economic land management tool. The unique New Zealand environment does not allow for direct adoption of other nation's prescription fire protocols. Scientific research is required to: understand safe prescription windows for all regions; determine fire behaviour and smoke transport within these windows; and develop end-user tools to assist with understanding the high-risk 'no-go' prescription fire days. Historically fire was an important land-clearing tool. However, use of fire has decreased due to regulation and social concerns leading to loss of skill and knowledge. In the ever-tightening economic climate of the future, this is a loss of a valuable cost-effective tool.
Research components	*Component 1: Developing benefit windows* Research is needed to determine the windows of opportunity whereby benefit from the hazard can be accessed. Fire is an effective land management tool when the risk of escape is lowered and smoke impacts are mitigated. Prescription windows are windows of opportunity when a burn can safely take place given current weather and available fuel conditions. These windows define minimums and maximums of variables important for fire behaviour and smoke transport. Defining the conditions of tolerable fire and smoke behaviour within each region of the country is necessary to develop optimal prescription burning windows. *Component 2: Quantify hazard-use dangers* Understanding hazard dangers is necessary before accessing their benefits. For fire, observation and model campaigns are required to evaluate fire and smoke behaviour in the productive and natural ecosystems. Prescription fires are often low-intensity surface fuel fires and globally little research has been done for this fire type. It is difficult to predict the potential escape of a fire while this knowledge gap remains. *Component 3: Application of science* A successful hazard benefit program

	requires technology and equipment that assists those accessing the benefit. For prescription fire this is the Rural Fire Authority, agricultural and forest owners, and others who conduct land management burns. The scientific results found during development of benefit windows (i.e., prescription fire window) and quantification of hazard-use dangers (i.e., fire and smoke behaviour research campaigns) require translation into useful applications, such as texts that push information (i.e., 'warning: wind speed has increased').
Research Gaps and Opportunities	Benefits exist after most natural hazards, however accessing those benefits in a timely fashion rarely occurs due to lack of science, technology, and framework development prior to the hazard. In addition, some hazards can be used in controllable scenarios to the gain of the communities. For example some agricultural regions use controlled flooding to assist with agricultural production and in New Zealand, recent recommendations for wilding control have included fire as part of the method for elimination. Current research is working to investigate the risks and benefits of using fire as a rural land management tool in New Zealand. There is no New Zealand-wide set of defined guidelines or protocols for prescription fire. The prescription fire scientific gap has been acknowledged through both land management agencies and Regional Councils. There is a large unknown surrounding the consequences of an escape into native New Zealand ecosystems. Questions that need addressing are: what is the recovery period?; what is irrevocably damaged?; how does fire spread in these systems?; what type of smoke is produced?; and others. Without scientific investigation into these areas of research, the exact risk of prescription fire for locations near native ecosystems cannot be fully quantified.
Comments	Potential collaborators: FOA, DoC, Regional councils, station owners, agricultural land owners
Theme 4 **Technology for hazard benefits and hazard devastation**	
Importance to New Zealand	Intelligence (situational awareness) technologies developed for fire are transferable to other hazards – earthquake, tsunami, volcano, pandemic, war. The technology for intelligence gathering has increased exponentially. With excellent real time intelligence hazards can be identified and suppressed or conversely controlled as a valuable benefit (e.g. use of fire for weed control in the landscape). New technologies and their integration into common use will be essential for the application of the four 'Rs' of disaster management – Reduction, Readiness, Response and Recovery. Rural fires are emergency events which often occur in isolated places far from communication infrastructure. Unchecked, fires can burn into valuable resources (plantation forests, protection forests, farmland, structures and towns). Ever improving technology provides the opportunity to monitor fire suppression activities in real time across the landscape and display the activity in virtual reality.

	Current understanding of future climate and land use changes prognoses fire as an increased risk on the hazard-scape. This will create smoke hazards for urban interface or lifestyle block communities. With excellent intelligence and prediction models smoke hazards will be eliminated while allowing for the use of fire as a tool for land management.
Research components	*Component 1: Define new technologies* Define the type of technologies that should be developed or combined to collect valuable data from hazards, such as fires. For fire this includes location, fuel type, flame size, travel speed, smoke chemical composition and plume characteristics. Determine how the data should be presented to fire managers and others. *Component 2: Use existing technology* Advances in computer visualisation and gaming software can be used to provide geo-referenced intelligence, for example on a 3D digital interactive sand-table. This rich immersive information presentation can be used to prepare for or orchestrate the response to a hazard. For fire this would include resource placement, defining values at-risk, and understanding fire location relative to impacted communities. New 4G cellular networks and satellite communication will enable data from sensors (e.g. video, gps location, smoke composition, temperature) to be streamed to command centres to provide in-field intelligence during ongoing response.
Research Gaps and Opportunities	The technology for fire suppression has been little improved over the last 50 years. To progress fire suppression and other hazard response there is a need to develop intelligent and miniaturised sensors that assist with relaying information of ongoing events to command centres. In addition, teleoperation and robotics have not been harnessed for wildland fire suppression and intelligence gathering. This is a clear gap whereby existing entities within New Zealand have the skill and ability to fill. Successful novel wildland fire suppression tools will be taken up by fire suppression crews around the world. Close linkages exist between the fire experts (Scion) and the communications, electronics and robotics expertise in Christchurch. New Zealand can further capitalise on this hub of expertise and the vast pool of skilled students and supervising scientists. Current established collaborations include Scion and Tait Communications and Scion and University of Canterbury – Computer Science, Electrical Engineering, Mechatronics, Geography, Mechanical Engineering, Geospatial Research Centre, NZi3 and Forestry. Future-proofing fire management for these changes requires advanced scientific modelling of fire behaviour, smoke transport, and fire-weather interactions. Progress towards state-of-the-art coupled fire-atmospheric models will enhance the capabilities of existing and under development information tools. Fire and smoke behaviour tools of the future will progress this coupling as well as link to climatic and land use changes.
Theme 5 **Impact of future changes on hazard management and preparation**	
Importance	The goal is to future-proof hazard management for changing climate, land use,

to New Zealand	and human dimensions through technological advancement and scientific understanding of future hazard occurrence. New Zealand fire occurrence is closely linked to climate and human changes Risk of hazard impact will increase or decrease depending on climate, population dynamics, and land use. Preparing for these changes is difficult without understanding the likelihood of the type or frequency of hazard impact. The risk posed by rural fire in New Zealand is increasing. Increases in rural and urban population interfacing with forest and agriculture lands will place communities closer to those using fire as a management tool. An increase in fire climate severity is also predicted due to climate change over the next several decades. The changes in these and other risk factors have the potential to result in different types of fires than previously experienced due to natural and human caused vegetation shifts. Extreme fire events are likely to occur more often resulting in increased populace exposure to fire. Future-proofing fire management for these changes requires advanced scientific modelling of fire behaviour, smoke transport, and fire-weather interactions. Progress towards state-of-the-art coupled fire-atmospheric models will enhance the capabilities of existing and under development information tools. Fire and smoke behaviour tools of the future will progress this coupling as well as link to climatic and land use changes. Technology can be used to assist with land management planning for the future ecosystems by linking dynamic vegetation progression models to the New Zealand Fire Danger Rating System. This link is important to fully understand how fire use, extreme fire risk and land management preparedness will change with a changing future.
Research components	*Component 1: Link hazard occurrence to future predictions* Link current understanding of hazard occurrence to climatology, human dimensions, and other predictions important to that hazard. For fire the link between current fire climatology and dynamic vegetation models is needed to determine the interaction strength between the two and future fire risk. *Component 2: Progress models* Progress hazard modelling such that the link to the climate, land use, and population changes is maximised to give the best information. Fire requires further development of fire and smoke behaviour models that are coupled with meteorological models so the fire-atmosphere interaction can be fully studied and results translated into the existing fire danger rating system. *Component 3: Future proof* Use scientific results and advance technology to develop a flexible framework for disaster management. This is done through development of models and technological transfer methods that are flexible and capable of operation over a large range of hazard scenarios.
Research Gaps and Opportunities	Opportunities exist to collaborate internationally with USFS and Bushfire CRC to develop the science and technology needed to fulfil this theme.