OFFICE OF THE PRIME MINISTER'S SCIENCE ADVISORY COMMITTEE

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Thank you for the opportunity to speak.

NIWA seems a particularly appropriate venue to address what might at first glance appear to be two apparently unrelated topics – the CRI reforms and the broader issues of public confidence in science associated with the climate change debate. But these two issues both reflect different parts of the same fundamental principle – that science is playing an increasingly central role in our society.

Science is fundamental to how we live our lives and how we address the challenges ahead of us on an increasingly compromised planet – protecting our environment while responding to the demands of economic growth and enhanced productivity, improving the way we live in an increasingly complex and networked society, and maintaining and enhancing the relevance of New Zealand in the world.

My close friend Lord Robert Winston has elegantly pointed out in his new book *Bad Ideas* that humankind evolved with the essentially unique capacity to use technologies in ways of escalating complexity. In many ways the history of our species over the past 100,000 years has been one of developing new technologies and using them for advancing the way we live, but at the same time having to deal as a society with the downsides of those new technologies.

A stone tool can be used as a way to build shelter and get food, or it can be used as a weapon. Agriculture brought new food sources but the possibility of famine if the harvest failed. Cities brought the opportunity for cooperation and the specialisation of labour, but also the threat of epidemic disease. But technological advancement accelerated with the scientific enlightenment of the middle of the last millennium, in which empiricism and hypothesis formation and testing started to replace Aristotlean logic and Platonic teleology in understanding our world and our place in it. We now recognise that we are part of a world which was not built for us, but that is increasingly fragile as a result of our activities. In the second part of this address I shall return to this theme.

Indeed, this year we are celebrating the start of this technological transformation in the 350th anniversary of the founding of the Royal Society – the world's first scientific society whose formation in 1660 was a direct reflection of the emergence of a way of understanding knowledge that was first known as experimental philosophy and which we now know as science.

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The transformation is by no means complete – too many decisions are still based on dogma rather than knowledge – but what is obvious is that the exponential rate of progress in knowledge formation is challenging us in many ways. It is no longer clear how we can understand and integrate all the knowledge we can now accumulate and we are now using science to address questions of complexity and fundamental importance to every domain of our existence that we would not have dreamed about even two decades ago. That we can even model climate change at all is a reflection of how far we have come.

We need to accept that the world is changing at an exponential rate, that knowledge and technology are a major part of that change and whether New Zealand remains of relevance to the rest of the world or not will depend on transformational strategies than in turn will depend much on how we develop and use knowledge.

A knowledge-based society will be more ambitious, more prepared to face the challenges ahead, more able and willing to address issues of social development and environmental protection, and certainly more productive. Studies by the OECD show a remarkable relationship between a nation's investment in RS&T and productivity: nations that invest more in RS&T are the most productive. There is a global consensus that investment in science and innovation drives growth, few would now consider that this relationship is simply a reflection of wealthier countries investing more in research.

But in New Zealand there has been a collective avoidance of the significance of this relationship for nearly 30 years. As a whole, we spend only 1.2% of GDP on research, about half of that from the public sector and half from the private sector. Comparator small but progressive nations spend somewhere between 2 and 3 times that amount.

Furthermore, it is the private sector that makes a much more significant contribution in other nations. If we just compare ourselves to Denmark, a nation that like New Zealand, was very much based on food production. In 1980 we and the Danes invested very similar amounts in research, science and technology.

But between 1980 and 2010, if we were to have spent at the same rate as the Danes we would have invested some 44 billion New Zealand dollars more in science than we have, and at least 60% of that would have come from the private sector. I have no doubt that it is this cumulative under-investment in knowledge that explains why in OECD ratings our productivity relative to that of Denmark has declined so far and we are ranked surprisingly low on scales of innovation. And poor economic performance inevitably leads to poorer social performance.

Let me suggest some reasons as to why this has been the case:

At the heart of it I think we have a set of really deep cultural issues. We have been seduced by our national mythology – "number 8 fencing wire", "punching above our weight", "we think we are innovative" when the report of the OECD and the recent report from the New Zealand institute show that we are not.

Has our strong egalitarianism led us as a country to avoid a focus on intellectual activity which is seen as elitist. Is it that our current spending pattern was established in the post war period of protectionism and farming for Britain at a time when commodity was king and in that time we built up an almost untouchable pattern of high social spending so that shifting expenditure towards

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productive areas with long delays before return, such as RS&T, is difficult especially when such strategic investment needs to be bipartisan and is hard when electoral cycles are short.

We also need to ask why is it that our private sector spend on R&D is so low? Could it stem from the chronically low public sector investment dis-incentivizing the private sector from seeing RS&T as exploitable because there has been insufficient ideas flow?

Has it been that the incentives in the public research sector drove it to an inappropriate degree of focus on late stage application rather than knowledge generation and knowledge transfer and this either displaced private sector investment or competed directly with the private sector? The CRI reforms and other initiatives in development address this.

Could it be that the NZ private sector is too focused on short term returns through commodity cycles and property rather than long-term growth? Clearly there is an issue of the availability of investment capital and the commitment of the New Zealand shareholder to more speculative investments or those with a longer term return. Perhaps some of the heralded changes in the tax system might assist the necessary shift in mindset. There are exceptions – look at Weta Digital and Fisher & Paykel Healthcare. Given the quality of science and engineering education in New Zealand, we clearly have a large unexploited potential for knowledge based industry growth.

There are many more issues – one of particular importance to this audience is that of the interaction between the public and private sector. Universities and CRIs have been so competitive and driven by their own bottom line considerations they have confused their role of being ideas generators with that of being their own ideas exploiters.

Excessive competition has hurt rather than helped. We have very few people skilled in knowledge transfer, we tend to work as lots of small individual and often parochial operations rather than going to scale by combining scarce expertise. Our skill base in managing and developing the knowledge based sector and in learning how to take it to scale internationally needs enhancement. This issue is occupying much of my time.

But as should be manifestly clear to all of you, there is now a more intense focus on the role of science in New Zealand's development than there has been for two decades. The Prime Minister sees science as being central to the nation's advancement and the Minister of RS&T is leading the most substantive changes that the science system has seen in more than 20 years.

There has been a major and fundamental shift in thinking and in particular a growing realisation in government that science expenditure must be seen as an investment in our country's future rather than viewed as a cost. But, like any investment, there needs to be clarity over its purpose. Slowly but progressively, the various elements of the New Zealand science system are being analysed, and as our economic situation allows the issues will be confronted.

With my appointment, we have seen a strengthening of the positioning of science within the highest level of policy formation, recognising that science has a broader part to play than simply in the narrow sense of Vote RS&T. The Minister of RS&T has issued a list of strategic priorities for the sector which represent a very progressive and forward-looking view of what science can contribute to New Zealand.

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The agency relationships are being addressed with the merger of the Foundation and the Ministry to create a more effective policy-driven unit for science and in time this will lead to more effective arrangements for the science system. There will be attention to improving the transfer of knowledge from the public to the private sector and strategies to increase New Zealand's private sector investment in RS&T. There is much more to do – the competitive funding system has multiple problems, the need for better infrastructure, the need to recruit more talent, these are all matters under consideration.

But let me focus now on the CRIs. Why did we give priority to addressing the state of the CRIs as a first stage in strengthening the science system? Why did the government establish the Taskforce and then decide to implement its recommendations?

Early after my appointment, the Prime Minister tasked me to consider the role of the CRIs. On analysis, it was very apparent that the CRIs were not delivering optimally and in the way that they could and should. Arguments had been advanced that maybe we did not need CRIs – that they could be merged with the universities. But while both are central parts of the public science system and their mission must overlap and intertwine, the need for sector focused research and development engines is clear.

It was clear that the Government should formally review the purpose of the CRIs and confirm the basis of their future. The issues were multiple, but fundamentally the CRIs had drifted significantly from their original intent. Much of the reason for that drift was lack of clarity by the shareholders of the reason for their existence. This in turn was reflected in the lack of depth in shareholder instruction to the CRI boards and the very inadequate descriptions of shareholder expectations and this in turn was reflected in incomplete measures of performance. This lack of clarity led the boards and management to drift, and any alignment with core missions was at risk. By default, performance and accountability became almost entirely focused on fiscal rather than research objectives, with a number of perverse consequences.

The CRI reforms will change all of this and more. Boards and management must and can now focus on the core purposes of CRIs. In a nutshell, this can be summarised as providing the capability and capacity necessary for the sector end users, whether public or private, to use knowledge and technology effectively. The CRIs must provide knowledge transfer and technology transfer to help their sector address immediate issues, they must undertake research which in time will advance the public interest and also assist the productivity of the private sector.

This research must occur over both intermediate time frames, where the research while still requiring public sector input has a clear route to application say over a 3-7 year window, and longer time frames where knowledge and capability is needed but the manner of application is more speculative and might be over a 7-20 year window. CRIs will have to allocate resources strategically across these four domains – importantly each domain needs different strategies and management approaches.

Note that, quite intentionally, I am avoiding the use of terms such as "blue skies" and "basic" and "applied" – the reason is that to the person who does not live and breathe the science process, there is a tendency to be at times to think almost pejoratively about the value of so-called "blue skies" and "basic" research. But the reality is that best expressed by George Porter, former president of

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The Royal Society – there are only two kinds of research – "applied" and "not yet applied". Every country that aspires to be productive in the 21st century must have adequate and balanced volumes of both types of research. Some of the most erudite research today may be the most exploitable tomorrow.

The major purpose of the reforms presaged in the CRI review and approved by Cabinet is to achieve alignment of mission and put the incentives in the right place. A key issue has been the nature of the funding arrangements. Because CRIs until now have acted essentially as research hotels, with their destiny controlled either by decisions of the Foundation or by contracts, CRI Boards have had almost no input into refining their mission and ensuring they can meet their potential. They have had little influence, let alone control, over their strategic direction.

This could not lead to good governance or sensible management. Because the only real performance measure was fiscal, the expectations and performance measures for CRI science were deficient. The Crown has now acknowledged that the purpose of CRIs is not to make money, although of course, like all Crown entities, they must manage their resources responsibly and follow basic principles of fiscal prudence – this is no different to any other Crown entity be it a hospital or the defence force. Rather, the Crown is making it very clear that the key expectation is that the CRIs make a real difference to the sectors they are there to support.

These are not just words. I am talking about real and significant culture change. First, culture change by the owner, that is the Crown, and this is made much easier by the merger of the Ministry and Foundation. But even bigger culture change will be needed in the CRIs themselves. Some in CRIs, in Boards and in management and amongst staff may have totally underestimated the magnitude of change that is required. Some CRI staff seem to think nothing will really change. If you do not get out of that mind-set you will be in real trouble. The expectations are now on real quality in decision making and performance.

What are some of the changes that will be needed?

There has to be an enormous focus on technology and knowledge transfer. CRIs are not there for self aggrandizement – they are there to provide and develop knowledge the sector needs. And that means a focus on getting the knowledge and technology to the sector. CRIs will have to develop measures to demonstrate this. CRIs are there to support the private sector rather than compete with it, and an enormous amount of historical suspicion will have to be broken down.

CRIs must look after the Crown's money responsibly – but they are not there to make money, but rather to help New Zealand make money, protect its environment, and advance its social and economic wellbeing. This means getting out of the competitive mindset and into the collaborative mind set – this is a challenge for the entire science system in this country. The CRIs need to take a greater role in human capability development and get into better partnerships with each other and with universities.

With more bulk funding comes the need to have the skills in strategic science planning. This means becoming focused on the mission and the sector. There has been activity sustained in some CRIs just because the CRI could get funding to do it, not because they should be doing it. Why should a CRI be doing work on human health care? – rather, they should be collaborating with those mandated to do it.

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How many CRI managers know they have staff working in an area not because it has long term potential for the sector but because of the way funding has been achieved – they have to continue the activity or lose the funding – that has an opportunity cost. The shift to bulk funding is meant to get beyond this. Now CRI managers will have the capacity to say – this is a field whose time has passed, let us start winding it down and shift the staff to a more productive and relevant area. Having the skills to stop research is as important as identifying new areas.

Equally, their planning must ensure that capacities that really matter now or will matter in the future get maintained – areas that may not have been sexy in the pure competitive model but are essential to the public good, like nitrogen fixation, need to be sustained and developed. CRIs should be thinking ahead not in isolation but in consort with the whole research community about infrastructural and capacity needs.

Again, do not underestimate the magnitude of these challenges – they exist at every level
The statement of corporate purpose will be a negotiated clear description of what a CRI exists to do and out of that, together with the statement of corporate intent, has to come a clear statement of assessable measures of performance.

It is easy to measure knowledge and technology transfer and industry support. It is more difficult but no less important to define the intermediate and long-term research and development strategies and goals and to justify when and why a CRI continues to control an exploitation path rather than move it to the private sector. Business development will become more about technology transfer than focusing on internal exploitation for bottom line purposes.

The CRI boards will need to accept that just because there is a broader range of responsibility that does not necessarily mean more dollars. They will have to rebalance their activities .They are going to have to learn to prioritise within this new range of responsibilities. All said and done that is what every research institution in the world does. They will have to find the right balance between different types of activities including partnership formation, capability development and relationship management alongside the research domains we have already discussed.

External Scientific Advisory Boards will be required because second rate research is a waste of money, and any institution in science that does not open itself up to evaluation by other scientists cannot do the best by its funder or its end users.

End-users need to understand and be involved so that alignment is maintained. That does not mean that end-users should control what decisions the Board makes – indeed they must not – but there needs to be a mutual understanding of what knowledge is needed and what new knowledge might mean for the sector.

Change is going to be hard because we have had a generation of scientists and science managers grow up in a world where competition to the death has been king – too much innovation has been unnecessarily closed and strategic overview has been lost. Performance measures have not been transparent and aligned.

Every scientist, manager and board member in the CRIs now has a collective responsibility to contribute to the change that is needed. Simply put, New Zealand cannot afford to waste this opportunity.

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The Prime Minister has made it clear that science is at the centrality of his vision for New Zealand's future – you would all agree with that. Even though times are tough economically, the CRI reforms and the science system in general have received a substantial amount of high level effort and intention. This has not been for just superficial rearrangement, this has been for significant, deep and effective change. No-one denies that both the public and private sector need to invest more in science but we must not waste what we have.

We are only 4 million people and we are not as rich as we should be. We cannot do everything. We must manage our resources well and use our collective strength rather than waste effort on internal competition if we are to have a better future.

And on that future facing note let me shift to the second component of my presentation.
I am not going to enter the debate about whether the world is warming and whether that warming is anthropogenic. That that is the position that has been reached by the global climate science community and is reflected in comments and conclusions of authorities and bodies far more expert than I: I refer for example to recent statements from the chief scientists of the UK, USA and Australia and the Energy Secretary of the USA, multiple national academies, and the recent UK meteorological office summary of evidence since the last IPCC report.

I think that the simplest statement of the consensus would be that the atmosphere is accumulating more greenhouse gases, and this is having warming effects on the planet as reflected not only in physical measures but in multiple biotic changes. These changes are mostly caused by human-induced changes affecting greenhouse gas emissions. These conclusions are not affected by the recent controversies surrounding the IPCC process. Indeed new data and analyses since the 2007 IPCC report continue to reinforce these conclusions.

Everyone acknowledges that climate is a complex system and there is much yet to understand and thus many uncertainties and unknowns. Indeed the IPCC process was established to allow a synthesis to be achieved across multiple domains. But while solar activity, volcanic eruptions, and weather patterns (such as the El Niño / La Niña cycle) influence climate from year to year, on a time scale of several decades the effect of these natural influences is insignificant compared to the effect of human-induced greenhouse gas emissions.

The degree of global warming will vary in different geographical locales and there is uncertainty about the timescale and magnitude of effects caused by climate change, although *not* about the direction of change. The implications for society in terms of food and physical security and regional conflict are very real and cannot be ignored by politicians.

At the heart of the IPCC process and other climate change analyses is an attempt to predict the rate of warming which will be driven by greenhouse gas emissions so as to develop a risk profile. Like any other prediction process there is a range of scenarios that have emerged encompassing the range of probabilities involved.

There is also agreement about the latency between greenhouse gas emissions and their effect on global climate. An increase of greater than 2 °C is generally accepted as creating significant challenges and risks. Even if significant reductions in greenhouse gas emissions can be achieved within the next 10 years, modelling suggests there is only a 50% chance of limiting global temperature rise to 2 °C. The consensus extends to recent analysis which suggest that the 2 °C target

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is becoming unlikely to be met, and that a rise of 4 °C this century is becoming increasingly likely. Under the worst case, business-as-usual, scenario, this point might be reached by around 2070, well within the life span of our children.

Although New Zealand contributes only a small fraction of global greenhouse gas emissions, it has a unique emissions profile. We are the only 'developed' nation in which agricultural emissions (mostly methane) are as significant as other sources. Methane has a much shorter atmospheric half-life than CO_2 but is more than 20 times as potent a greenhouse gas, making it an attractive target for emission reduction measures.

This why New Zealand has taken the lead in the development of the Global Research Alliance for reducing greenhouse gas emissions from agriculture. The meeting held in Wellington 2 weeks ago was productive, and I am suspect we will look back at it in a decade's time as the formative event in what might be a critical scientific process and one that New Zealand has initiated. We have to increase food production in ways that generate acceptable water and energy footprints while at the same time reducing emissions. These are difficult challenges.

Now all of this has been easy to say, but every scientist and science leader who makes such statements risks getting attacked and often in an *ad hominen* manner. But the challenge is not really a debate about climate change *per se* because there is no broad scientific disagreement over the basic principles, although scientists do and should always debate the observations and implications and of course the science will develop and predictions will change.

Although there has been genuine and appropriate debate about anthropogenic warming in the last 20 years through the peer review process, in recent times the consensus has been much more complete than has been presented to the public. To quote the UK Chief scientist Prof John Beddington in his statement to the House of Commons Select Committee enquiry into the East Anglia affair "human induced global warming is happening; it is induced by human activity".

The scientific community does not have trouble with evidence-based evaluation of data even when controversial, as long as the debate is scientific and unbiased. In theory, we must accept that data could still emerge that could lead to a change in the conclusions reached – and the science community would accept that – but in reality this is an extraordinarily remote possibility given the body of evidence which continues to reinforce the consensus reached.
We have to accept the reality that our impact on the planet is real and is limiting our futures in many ways – not just climate change, but water security, food security, and energy security. And the solutions to this set of challenges are both multifaceted and common.

But what is really worrying me, and was a particular topic in my discussions with both President Obama's chief science advisor Dr John Holdren when I met with him in Washington recently and in my recent discussions with my counterpart in Australia, was the effect that such attacks might have on public confidence in the integrity of the science system.

Of course that means every scientist must act with the highest level of personal integrity. But scientists are human and there will always be those who do not get beyond their biases, or are careless or are fraudulent. Fortunately the scientific enterprise is built on publication, repetition, peer review and the inherent scepticism and questioning of scientists. The multiple dimensions of

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modern science and science communication do not allow fundamental flaws in logic to be sustained for long.

The IPCC process was not perfect but it was not fundamentally flawed – it was inevitable with so many involved that there would be some errors. Indeed the few errors picked up, a handful in nearly 20,000 referenced papers, have been of no significance although they have been magnified for reasons I will discuss in a moment. We all know we have had minor errors we have missed in papers we have published or reviewed. the UN itself understands the need to restore confidence in the process and the IPCC process itself is under review by a panel nominated by the major academies.

The public's understanding of certainty and uncertainty is variable and this has been played on by those with explicit agendas to undermine confidence in science as happened in the tobacco industry with respect to smoking. And of course the public has been confused by the apparent need to give moral equivalency to so called sceptics. But I think that most of the public has understood that, despite some level of uncertainty, the principles of risk management require that responsible governments have to make decisions despite information being inevitably incomplete.

So why the attack on the climate change consensus and the vehemence of the attack? Is its nature such that it cannot be seen as a scientific debate? Is it really about whether the world is warming or not or is it fundamentally about whether and how the world should respond. Is it that this response involves a number of decisions that are perceived to impact on economic and individual freedoms, and this particularly worries those with libertarian values? Is it that the concept that humans are not free to do what they like in their world and that every problem does not have a technological solution, that would preserve that freedom, is at the heart of their concern? A further concern emerges from the issue of what is fair and what is not, who should follow and who should lead.

And that is why the dialogue is so complicated. Every science leader agrees that we should engage with the public on matters of science. But here we are not really engaging solely on a matter of science. Science is influencing policy and thus interacting very directly with political frameworks. Science is engaging with a belief system and this has the same problems as the evolutionary biologist engaging with the creationist – how can a constructive dialogue be held?

And like the intelligent design debate, the argument is framed in scientific terms and yet whatever the evidence is provided, for some no evidence will be enough. There would be no observation that could shift their opinion. And this creates a bigger issue. The changing nature of the information commons is that data is increasingly in the public eye – and that is how it should be. A lesson from the East Anglia affair highlights the value of making data publically available but it also highlights the costs of making it interpretable –especially large complex data sets.

But the science community must accept this will be the way of the future. This is a big challenge for modern science; information is becoming more accessible and because science interacts with and pervades every aspect of society, scientists now need skills to engage beyond the peer review process. Yet the skill of most scientists is in debating other scientists, rather than facing challenges from the non-scientific community. Not every scientist has the skill to communicate across this boundary.

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The University of East Anglia story highlights this; the university responded to legal but very high volumes of requests by not making data accessible, fearing a deluge of cost and diversion if they did. The excuse of closed innovation, the confidentiality of data, was one of the arguments used. As we now know from two independent enquires, this was a mistake but there was no fudging of the data or malpractice by Professor Jones and his colleagues although their behaviours added fuel to a fire. We should not be arrogant and believe that every person who contradicts a generally held scientific conclusion has the motives I described.

As I said, every scientist is trained to engage in proper scientific debate but much of the argument has not really been about science even though conducted in scientific jargon. This is a real challenge for public science and people such as myself - how to address a discourse which must occur beyond the boundaries of science - when the discourse is based on belief and ideology, resolution cannot be easily achieved.

Take evolutionary biology – we have a broad consensus over how evolution operates but for a large number of people it is not acceptable because of their belief system. There is no experiment or observation that would persuade those of fundamental belief to change their belief system. Yet as an evolutionary biologist I can conceive of are theoretical but now totally implausible observation that could destroy my scientific understanding of evolution – for example finding hominin skeletons in a pre-Cambrian rock formation. Similarly in climate change – we can hypothesise observations could in theory emerge that would change our predictions for the future but they have not emerged despite the enormous global climate change research effort.

Then there are the conspiracy arguments: for example climate change is a giant conspiracy to get science funding. This is bizarre. Every government would love it if there was no such thing as climate change. Every government chief scientist including myself would love to duck the issue. There is no advantage in diverting economic activity in the direction of and amelioration of greenhouse gases, especially when those decisions have a political cost. Yet while politicians have not got entirely over the complications of domestic politics, which limit their responses, as a whole they have reached a remarkable consensus. Risk management requires action even if it is unpalatable.

But there are issues we have to face. Science has changed – we live in a world of intense competition, of potential bias in peer review particularly in narrow fields, there is a growing commercial focus to much public sector research – these changes have affected the way science operates. Do these things indeed change the way public perceives science? These are deep issues and we cannot ignore them. I shall return to this theme in an address in Wellington later this year.

A fundamental part of my job is to ensure public confidence in and understanding of the science system. In even opening up this discussion I have invited, and in fact received, *ad hominen* responses. But the scientific leadership has no option but to ensure that the dialogue is as informed as we can make it. Our society depends on open, informed and civil dialogue and our science must operate to the highest levels of integrity and openness. The challenges will become greater as science and technology continue to offers new opportunities to society and stretch the boundaries of human imagination and knowledge. The pace of discovery can rapidly outstrip public confidence in the science system.

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Science is the basis of our future development as a nation. Globally the challenges of feeding more than 9 billion people, of sustaining food, water and energy security are real. Failure could readily lead to conflict and suffering. Yet in addressing these issues, environmental security is equally important; if global temperatures rise then the challenges will be even greater. The work that NIWA and the other CRIs do is essential to our national development.

Thank you.

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